

EARTHQUAKES

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INDIANS DANCING TO CELEBRATE THE DESTRUCTION OF THE WORLD. [*Frontispiece.*

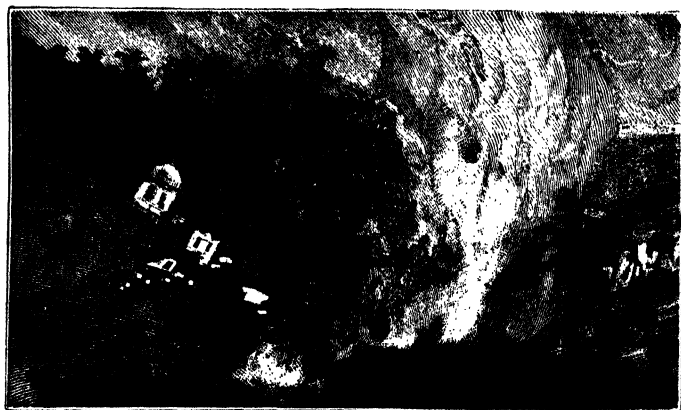
EARTHQUAKES

TRANSLATED FROM THE FRENCH OF

ARNOLD BOSCHOWITZ

BY

C. B. PITMAN



VILLAGE, FOREST, AND FIELDS DISAPPEARING IN AN ABYSS

WITH FIFTY-SEVEN ILLUSTRATIONS

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CONTENTS.

EARTHQUAKES.

PAGE

Impression made upon Men and Animals.—Suddenness of the Catastrophe	1
---	---

THE FOREWARNINGS.

The Ancients believed that Earthquakes were preceded by phenomena of various kinds. - Earthquakes followed or preceded by Meteors.—Anxiety of certain animals previous to a severe earthquake.—Instruments giving warning of the imminence of Volcanic Eruptions and Earthquakes . . .	8
--	---

THE CATASTROPHE ITSELF.

I.—THE SHOCKS.

Difficulty of observing the motions of the soil during severe Earthquakes.—Three different motions.—Undulations and Earthquake Shocks in Calabria in 1783.—Motions of the ground which destroyed the town of Riobamba, in Ecuador.—Duration of shocks	18
---	----

II.—THE UNDERGROUND NOISE.

Earthquakes are not always preceded by underground noises.—Nature and Explanation of the latter	30
---	----

III.—GULFS AND CREVICES.

Earthquakes create deep fissures in the soil.—Crevice suddenly formed	34
---	----

IV.—SPRINGS, LAKES, AND RIVERS.

Rivers suddenly change their course.—Movement of Lakes.—	
Modification of springs	3

V.—ERUPTIONS OF LAVA, FLAMES, AND EFFLUVIA.

Streams of mud descend from the mountains and submerge the plains.—Catastrophe upon the upper plateau of Riohamba.—Burning gases issue from the ground.—Exhalations injurious to plants and animals	
---	--

VI.—EXTENT OF THE DISTURBANCE.

Undulation of the water and terrestrial undulations.—Nothing arrests the spread of the destroyer.—Earthquakes which have extended to a great part of the earth's surface . . .	
--	--

THE UPHEAVAL, SUBSIDENCE, AND SLOW
UNDULATION OF THE SOIL.

I.

The coasts of Chili upheaved by underground shocks.—A territory suddenly upheaved in New Zealand	
--	--

Subsidence of the Valley of St. Eufemia.—Disappearance of the Town.—Great disturbance of the territory of Cutch, in India.—How the Japanese Lake of Biva was formed . . .	
---	--

III.

Destruction of Sodom and Gomorrah.—The story of Lot's wife.—Aspect of the region.—The Dead Sea.—The Jordan .	
--	--

IV

The coast of Puzuoli.—The Temple of Serapis	
---	--

V.

Measured undulations of the soil.—Pressure exercised upon the soil by the ocean and the atmosphere.—While one portion of the globe is slowly being raised, the other portion is gradually being lowered.—Character of this slow and universal undulation	68
--	----

SEA-QUAKES AND DELUGES.

I.

Vessels meeting shocks while at Sea.—The agitation of the Sea.—Waves raised up by the disturbance in the bed of the Ocean.—The great wave during the St. Thomas earthquake.—The Russian frigate <i>Diana</i> in the Bay of Simoda.—Flooding of the Peruvian coast.—Marine undulations caused by earthquakes	75
---	----

II.

Deluges and Earthquakes in Greece and China.—Atlantis swallowed up in the Ocean.—The Universal Deluge . . .	85
---	----

EARTHQUAKES IN THE ISLAND OF
ST. THOMAS.

I.

The Virgin Islands.—St. Thomas, the most beautiful island of the group.—Often visited by cyclones and earthquakes.—Cyclone and earthquake in 1837	94
---	----

II.

Cyclone of Oct. 29, 1867.—Energy of the Inhabitants.—Earthquake of Nov. 18, 1867.—Weather very calm at the time.—Underground mutterings.—Violence of the shocks.—Collapse of the town.—An enormous wave rise up in mid sea.—Terror of the inhabitants.—The wave invades the ruins of the town	102
---	-----

	PAGE
VOLCANO FIRES AND EARTHQUAKES.	
I.	
Volcanic eruptions followed by violent shocks.—Earthquake in the island of Java, and eruption of the Maunaloa volcano.—Shocks and volcanic eruptions in the islands of the Indian Ocean	114
II.	
The craters in ebullition regarded as safety-valves.—The Pasto volcano and the Riobamba earthquake.—The German traveller Reiss at Pasto	117
III.	
A mutual law seems to exist between volcanic eruptions and earthquakes	120
IV.	
Earthquakes in South America.—Are they due to the filling up of underground caverns?—Close connection between earthquakes and volcano fires	122
 THE CATASTROPHE OF CARACAS.	
The upper valley of Caracas.—The town of Caracas before the catastrophe.—Suddenness of the earthquake.—Violence and duration of the shocks.—Destruction of the town.—Number of victims.—The tending of the wounded.—Magnitude of the disaster	129
 AN EARTHQUAKE IN HONDURAS.	
Volcanoes of Central America.—Frequency of the shocks.—The Lagoon of Criba.—Gust of wind and earthquake.—The waters of the lagoon are upheaved.—Immense column of water	140
II.	
Aspect of a virgin forest after the catastrophe.—Destruction of the town of San José.—Emigration of the inhabitants . . .	147

THE CATASTROPHE OF SAN SALVADOR PAGE
150

HOW THE EARTHQUAKE EXTENDS.

I.

Motion of the soil at the centre of the shock.—Terrestrial waves running parallel with mountain chains.—Velocity of the waves athwart rocks.—Wells and grottoes weaken the shocks.—The wells of the capitol.—The crevices and grottoes of Quito 162

II.

Central earthquakes.—Linear earthquakes.—How their waves skirt obstacles in the way 167

III.

Difficulty of giving with precision the average speed of the terrestrial waves 169

IV.

Simultaneousness of the shocks.—Earthquakes occurring at the same time in places very far apart.—Is there a connection between them? 170

V.

At what distance from the surface do the shocks originate? —The method employed for fixing this distance 174

VI.

Land prone to be disturbed.—Why buildings of stone and masonry cannot withstand violent shocks.—The best way to build houses in regions prone to trepidation 176

THE LISBON EARTHQUAKE.

I.

Three shocks destroy Lisbon.—All Saints' day.—The numerous deaths in the churches.—Aspect of the city in ruins.—The bed of the Tagus is upheaved.—Falling in of the principal quay.—Tumultuous motion of the sea.—The King at Lisbon.—Flames and smoke.—Oscillations of the soil in Spain 180

II.

Extent of the earthquake's sphere of action.—Part of Europe is disturbed.—Violent undulation of the Atlantic Ocean.—The island of Madeira.—Agitation of the Caribbean Sea .	189
---	-----

THE EARTHQUAKES IN CALABRIA.

Calabria.—Earthquakes of 1738 and 1693.—The catastrophe of 1783.—The catastrophe of Polistena.—The rock of Scylla and the Prince of Scylla.—Victims buried beneath the ruins	194
--	-----

THE ISCHIA CATASTROPHE.

I.

The Island of Ischia.—Mount Epomeo.—Greek colonies.—Eruption of Mount Epomeo.—Ancient disasters.—The shocks of 1883.—The catastrophe of 1884.—Incidents at the theatre of Casamicciola and the Picciola Sentinella hotel.—Child saving its mother.—Acts of heroism.—The Bishop of Caserta.—Girls rescued after remaining underground several days.—Hallucinations of other persons rescued.—The King of Italy's visit.—The cause of the disaster.—Future catastrophes	204
---	-----

THE ANDALUSIAN EARTHQUAKES.

The provinces which suffered.—Earthquake of Dec. 1884.—Panic at Seville.—The Giralda.—The disasters of the town and province of Granada.—Localities affected by it.—The crevice of the Cerro de Gogollos.—Destruction of Alhama and Abumelas.—Voyage of the King of Spain.—Cause of the shock	232
---	-----

THE GROUPING OF EARTHQUAKES.

PAGE

I.

Volcanic earthquakes and Plutonian earthquakes.—How to distinguish them 243

II.

A third group of earthquakes.—Fall of subterranean caverns.—Action of springs.—Settling down of mountains . . . 246

THE VALAIS EARTHQUAKE.

The Valais.—The valley of Viège.—Shock of July 25, 1855.—Destruction of towns and villages in the valleys and on the mountains.—The town of Grechen.—Fall of enormous rocks and blocks of ice.—Avalanche.—Propagation of the shock.—Child crushed to death 250

FREQUENCY OF SHOCKS AND THEIR
GEOGRAPHICAL DISTRIBUTION.

I.

Earthquakes are more frequent than is generally believed.—Periodicity of some earthquakes.—No country is certain of immunity 256

II.

How people get accustomed to earthquake shocks.—Frequency of the shocks in South America 259

III.

Shocks in Switzerland and Italy.—Destruction of the finest monuments in Greece 263

IV.

Shocks in Egypt and along the coast of Africa . . . 265

V.

- Earthquakes in Asia Minor and Syria.—Earthquake which rent the veil of the temple at Jerusalem.—Destruction of the city of Antioch.—Earthquakes in the extreme East.—Regions where shocks are unknown or very rare . . . 266

THE CATASTROPHE OF MENDOZA.

- The town of Mendoza before the catastrophe.—The disaster of 1861.—Incidents.—Rescues due to the intelligence and fidelity of dogs.—A French traveller had foreseen and predicted the catastrophe.—Recent warning.—Disquieting symptoms in the volcanic region around the town . . . 272 .

THE EARTHQUAKE IN THE ISLAND OF CHIO.

- Chio, the pearl of the Greek archipelago.—Patriotism of the inhabitants.—Earthquake in 1883.—The capital is destroyed.—Prompt supply of relief.—Fresh shocks . . . 285

EARTHQUAKES AND THE SEASONS OF
THE YEAR.

- Popular beliefs as to earthquakes and the seasons.—They are confirmed by recent researches.—Seasons during which earthquakes are most frequent.—Number of shocks winter and summer, and also day and night 290

THE UNDERGROUND FORCES OF THE
ATMOSPHERE.

I.—THE TEMPERATURE.

- Brusque changes in the temperature during shocks.—Great decrease in the temperature during earthquakes in Sweden and elsewhere 298 .

II.—THE PRESSURE OF THE ATMOSPHERE.

Observation made during the Calabrian earthquake.—Sudden drop of the barometer at the time of an earthquake.—How Humboldt accounts for this.—Great atmospheric wave produced by the Java earthquake.—Seismometer or seismographs, instruments indicating the motions of the soil.—M. d'Abbadie's seismometer.—The seismometer and the microphone.—Microseisms, or very slight trepidations of the ground.—Their analogy with severe shocks 302

III.—UNDERGROUND STORMS AND AERIAL STORMS.

Earthquakes accompanied by tempests and storms.—Cyclones and earthquakes at the mouth of the Ganges and in the West Indies.—Fireballs and strange lights during the Cumana earthquake of 1799.—Ozone and the earthquake in Andalusia.—What ozone really is 310

IV.—ELECTRICITY IN THE ATMOSPHERE AND
MAGNETIC STORMS.

Influence of shocks upon the electric state of the atmosphere.—Action of shocks upon the electric needle.—Red lights frequently observed at the time of severe earthquakes.—Nature of this light.—Magnetic storm following close upon earthquake shocks 318

EARTHQUAKES AT CUMANA.

Alexander von Humboldt at Cumana.—Destruction of the town in 1766.—The shocks of 1799.—Aspect of the sun.—Electric state of the atmosphere.—Action upon the compass.—Extraordinary phenomena.—Thunderstorm.—Bolids.—Strange light in the sky.—Impression produced upon Humboldt and Bonpland.—Panic of the inhabitants . 324

EARTHQUAKES AND THE HEAVENLY BODIES. PAGE

The sun and the earth.—Solar spots.—Herschel's hypothesis.	
—The spectroscope.—The sun is a fiery body.—Photosphere, chromosphere, and corona.—Cyclone and storm in the sun.—Volcanic eruptions in the sun.—Observations of Father Secchi, Trouvelot, and Janssen.—The solar spots and the clusters of asteroids.—Immense discharge of solar electricity.—Connexion between these solar phenomena, magnetic storms and earthquakes.—Influence of the heavenly bodies upon the destiny of the earth.—Action of the planets, the moon, and the sun upon the subterranean forces.—The cycle of Saros.—Astronomical time-table of earthquakes and of the dangerous period.—Observations and researches of Alexis Perrey, Falbe, and Delauney.—The moon and the subterranean forces.—Ocean tides and subterranean tides	333

THE EARTHQUAKE IN THE STRAIT OF SUNDA.

The Islands of the Indian Ocean.—The Strait of Sunda.—Java and Sumatra.—Frequency of earthquakes in the Strait of Sunda.—Catastrophe of 1883.—Eruption of the volcano of Krakatoa.—Shocks at Sumatra and Java.—Destruction of towns and villages.—Mainland and islands disappear in the waters.—New isles are upheaved.—Eruption of the volcanoes of Java and Sumatra.—Enormous waves swallow up the towns of Anjer and Telok-Betong. Destruction of the finest Buddhist temples.—The number of the killed.—Marine undulation.—An atmospheric wave oscillates around the earth.—The underground noises are heard at enormous distances.—Aspect of the sun during the earthquake.—Crepuscular lights	348
---	-----

EARTHQUAKE IN NEW ZEALAND.

"THE EIGHTH WONDER OF THE WORLD!"	367
---	-----

CONTENTS.

xv

THEORIES AND CONCLUSION.

PAGE

I.

The central fire.—Theories and hypotheses which it has suggested.—Why the existence of the central fire is admitted.—What the interior of the earth might be like.—A sun concealed in the bowels of the earth.—Gradual contraction of the earth's crust.—Falling in of caverns and settling down of rocks.—Electricity considered to be a cause of earthquakes.—The cycle of the seasons.—The sidereal influences 375

II.

Underground heat the main cause of earthquakes.—The underground thunder and the disturbance of the soil.—The earth and the heavenly bodies.—Incalculable energy of the forces which the earth nurses within her 391

LIST OF ILLUSTRATIONS.

	PAGE
INDIANS DANCING TO CELEBRATE THE DESTRUCTION OF THE WORLD (<i>Frontispiece.</i>)	
After the Catastrophe. A family escaping through the ruins of a town	1
The sky streaked with lightning flashes and meteors. The inhabitants regard them with terror, as presages of an earthquake	11
Forest agitated by earthquake shocks in Central America .	19
INHABITANTS OF RIOBAMBA DISPUTING POSSESSION OF FURNITURE AFTER THE EARTHQUAKE <i>To face</i>	27
A traveller listening to underground noises	31
Village, forest, and fields disappearing in an abyss . . .	35
Circular crevices and wells formed during an earthquake . .	38
Violent upheaval of the waters of a river during earthquake shocks	41
Flames and effluvia issuing suddenly from the ground . . .	45
Map showing the sea and continents disturbed in 1755 . . .	49
DESTRUCTION OF SODOM <i>To face</i>	58
Columns at the Temple of Serapis, near Puzuoli	67
The scourge—an allegory	75
“THE RUSSIAN FRIGATE <i>DIANA</i> TURNED ROUND LIKE A TOP” <i>To face</i>	76
LAND ENGULFED BY THE WATERS OF THE OCEAN DURING AN EARTHQUAKE <i>To face</i>	88
FAMILY TAKING FLIGHT UP A MOUNTAIN DURING A HURRICANE AND EARTHQUAKE <i>To face</i>	98

	PAGE
Immense ocean wave lashed up by earthquake shocks . . .	105
“CARRYING AWAY SHIPS, AND COVERING WITH ITS HOARSE ROAR THE DESPAIRING SHRIEKS OF SAILORS” <i>To face</i>	106
Distant Volcanoes causing earthquake shocks . . .	115
The Upper Valley of Caracas, the two pyramids of the mountain of Avila	130
NIGHT-TIME, AFTER THE CARACAS CATASTROPHE <i>To face</i>	132
Waters of a Lagoon Upheaved during an Earthquake . . .	141
An Emigrant and Vagrant Family, after an Earthquake . .	143
Inhabitants of San Salvador on their knees during the Earth- quake	148
INDIAN MARAUDERS LOOTING THE RUINS OF SAN SALVADOR <i>To face</i>	156
Underground Grotto giving way	163
The Town of Quito, Ecuador	165
RUINS OF LISBON CATHEDRAL, AFTER A DRAWING OF 1755 <i>To face</i>	180
A Ruin in Lisbon, 1755	185
INHABITANTS OF REGGIO AMONG THE RUINS. <i>To face</i>	196
The population of Polistena, Calabria, flying from an Earth- quake	199
Eruption of Mount Epomeo in 1302	205
THE POPULATION OF CASAMICCIOLA TAKING TO FLIGHT. ACTOR FATALLY INJURED, IN HIS COSTUME AS “PUL- CHINELLO” <i>To face</i>	217
Ruins of Abumelas, Spain	233
EARTHQUAKE IN THE MOUNTAINS OF ANDALUSIA <i>To face</i>	234
THE TOWN OF ALHAMA, AFTER THE DISASTER. SEARCH- ING AMONG THE RUINS <i>To face</i>	238
Fall of Rocks in the Interior of the Earth	245
Child Crushed during the Viège Earthquake	251
A VIEW OF THE VALAIS <i>To face</i>	252
Traveller accompanied by Indians in the Andes	257

	PAGE
Ruins of a Greek Temple in the Island of Delos	264
Monuments Destroyed by Earthquake at Antioch	269
Dog Sniffing the Body of his Master	275
RESCUE DUE TO THE INTELLIGENCE OF A DOG . <i>To face</i>	278
DISTRIBUTION OF RELIEF AFTER THE CHIO EARTHQUAKE <i>To face</i>	286
The Port of Chio	289
A Family Wandering in the Snow, to avoid an Earthquake Shock	299
Hurricane and Tempest	302
Storm and Lightning in the Interior of the Earth	311
CYCLONE AND EARTHQUAKE AT THE MOUTH OF THE GANGES <i>To face</i>	312
Magnetic Storm and Electric Storm	319
Portrait of Alexander von Humboldt	324
CHINESE FLYING FROM AN EARTHQUAKE . . . <i>To face</i>	324
The Arctic Sky, after a drawing of the Twelfth Century	335
Tumultuous Movement of the Floods in the Strait of Sunda	349
A Traveller Contemplating the Ruin wrought by an Earth- quake	377

EARTHQUAKES.



After the Catastrophe. A family escaping through the ruins of a town.

EARTHQUAKES

Impression made upon
Men and Animals.—
Suddenness of the
Catastrophe.

WHEN volcanoes are in eruption they inspire terror, and cover with ruins the region within reach of them ; but the naturalist, accustomed to brave their fury, is often able to contemplate

11

them without danger. He can select the convenient time and place for getting close to them, and can follow unmoved their long period of fury, while, if he has strong nerves and an iron will, he can watch in security the tumultuous scene which is unfolded before his eyes. In the spectacle which he contemplates there is a sense not only of grandeur but of beauty, which tranquillizes his perplexed spirit. This is not the case with the force of which we propose to treat. It is sombre and sudden like death, and, like death, mighty and mysterious.

The earthquake is the most terrible and the most alarming of the phenomena by which our planet is visited; and, after having felt one of those awful shocks, one quite feels with Humboldt that the deep and indescribable impression which a catastrophe of this kind makes upon us is not due to the images of all those great disasters handed down to us in history, which at such a moment rise up vividly before us. What has such an effect upon us is that we suddenly lose our inborn confidence in the stability of the ground. We have been accustomed to the contrast of the mobility of water with the immobility of the land, and all the experience of our senses has strengthened our sense of security. When the earth begins to quake the experience of our whole

life is destroyed in a moment. As Humboldt says:—"An unknown power suddenly reveals itself, and the repose of nature ceasing to be more than a dream, we are suddenly thrown back into a chaos of blind and destructive forces." True, indeed, is it that the impression which this terrible scourge leaves upon the mind is deep beyond all expression, and the nervous disturbance which ensues sometimes gives rise to the most singular phenomena among the inhabitants who have been the victims of it.

Most of the survivors of the catastrophe which befell the town of Caracas were for a long time subject to nervous disorders. They would roll convulsively upon the ground, and then jump up and accuse themselves of all sorts of imaginary crimes. At Philippeville (Algeria) again, after the earthquake of 1856, several persons lost the use of their speech, while upon other occasions, as at Broussa in 1855, there have been many instances of paralytic patients regaining suddenly the use of their limbs.

It would be thought that the deep and terrible emotion caused by an earthquake would only be felt in large towns, and that people inhabiting sparsely populated regions, like the South American Indians, and living in huts constructed of reeds and palm branches, would not be afraid of

earthquakes. Yet a long way from the coast upon which the towns and villages are built, in the vast solitudes of the Orinoco and the Magdalena, human beings are not less alarmed by this phenomenon, which terrifies even the wild beasts of the forest and the monsters of the deep. For animals are in mortal terror during an earthquake, and Humboldt relates that the crocodiles of the Orinoco, generally as silent as the ordinary lizard of Europe, escape in haste from the heaving bed of that stream, and make off with piteous groans towards the forest. During the shock which occurred in the Canton of Valais (Switzerland) in 1855, the owls, which are as a rule the most timid and suspicious of birds, gathered upon the trees nearest to the houses, while other birds, such as swallows, took their flight towards other lands. It has been noticed in the West Indies and elsewhere that during an earthquake, domestic animals, such as the ox and the horse, will get close to each other and tremble all over. During the series of earthquake shocks in Calabria a hundred years ago, the dogs howled so loudly and dolefully that they were killed, and the same was the case at Philippeville in 1856; while at Bougie, in Algeria, the very nightingales and other song-birds were so struck with terror that none of them uttered a note for more than a week.

In modern Greek the designation of an earthquake is "Theomenia," or "the anger of God." The Greeks have no other name for this scourge, and as they believe it to be a special and direct manifestation of the divine wrath, they would be very aggrieved if an earthquake were attributed to natural causes, the same as in the case of thunderstorms, famine, or epidemics. The word "Theomenia" accurately renders the impression which the scourge makes upon the populace, and the same idea is conveyed under another form in the exclamation of the Psalmist: "The earth shall tremble at the look of Him; if He do but touch the hills, they shall smoke."

Earthquakes have ever been a source of terror, and this is easily understood. Precautions can be taken against other calamities, but not against this. As Seneca observes: The port protects the sailor against the storm; we can take refuge from an overflowing river; our roofs protect us from torrential rain; the caves and cellars offer us a refuge from the lightning; and plague and other epidemics can be escaped by a change of residence. No evil is without its remedy, but against the earthquake there is no protection.

No destructive agent sacrifices so many lives in so short a space of time. Within one minute the town of Mendoza, the capital of a state in the

Argentine Republic, was reduced to a heap of ruins beneath which nearly all the inhabitants, numbering about 16,000, were crushed to death. In twenty seconds 17,000 persons perished during the earthquake which demolished the flourishing town of Caracas. The earthquakes in Sicily in 1693, and in Calabria in 1783, are each said to have been fatal to 80,000 persons; the one laying in ruins fifty, and the other three hundred towns and villages. Upon the 4th of February, 1797, the earthquake of Riobamba killed 120,000 persons in the upper districts of the Equator. The first and fatal shock which destroyed the city of Lisbon in 1755 lasted only five seconds, and this earthquake, which extended far out to sea and lifted the waters out of their bed, was fatal to 60,000 persons. In the year 526 a terrible earthquake shock in Italy killed 120,000 persons, and in the same year more than 200,000 were killed, during a shock lasting only a few seconds, at Antioch and several neighbouring cities. In Japan, and the archipelago of the Sound, shocks of earthquake have often destroyed and depopulated whole regions which were before studded with opulent cities and rich with crops.

There is no calamity to compare with it. It comes all in a moment, the earth undulates and quivers for a few seconds, in the course of which

mountains crumble, valleys are upheaved, rivers change their course, towns collapse like houses of cardboard, and human beings perish by thousands, disappearing with the cities which they have inhabited beneath the yawning soil or the abysses of the ocean which the dread visitation has lashed into fury.

THE FOREWARNINGS.

The Ancients believed that Earthquakes were preceded by phenomena of various kinds.—Earthquakes followed or preceded by Meteors.—Anxiety of certain animals previous to a severe earthquake. — Instruments giving warning of the imminence of Volcanic Eruptions and Earthquakes.

IN the regions where earthquakes are frequent the inhabitants have naturally been very anxious to ascertain whether the underground catastrophe is preceded by any premonitory indications.

The ancient Greeks were firmly persuaded that such was the case. An earthquake which had caused the town of Helice, situated upon the sea-shore, to be engulfed in the waters, spread terror throughout Greece, and the inhabitants were always afterwards upon the look-out for any phenomena which would, as they thought, reveal the approach of the calamity. Pausanias, the historian and geographer who lived towards the close of the second century before Christ, held that earthquakes are foreshowed by special signs, such as heavy rains, a long drought, a want of regularity in the seasons, the eclipse of the sun, the sudden drying up of springs, the hurricanes of

wind which root up the largest of trees, the fiery apparitions in the sky which leave a long train of light behind them, the new stars which suddenly appear in the firmament, and the pestilential vapours which emanate from the ground, such, according to Pausanias, are the "signs which Heaven employs to warn the human race." Most of the signs enumerated by Pausanias are still regarded by the popular mind as certain prognostics of the catastrophe, and this belief is sometimes justified by the event. Thus it was remarked that the summer preceding the Lisbon earthquake in 1755 was an extraordinary rainy one, and although there was a great deal of rain that summer all over Europe, it was noticed that the mischief done by earthquakes was greatest in those countries where the rainfall had been heaviest. Another instance is that of the earthquake in the Valley of the Viège (Switzerland) in 1855, the vibrations of which extended to France, Italy, and Germany. The year 1855 was a very wet one, especially in Switzerland, where rain had fallen for weeks together before the earthquake. Still, there are often earthquakes during a long drought, so that neither rain nor drought can be regarded as certain forerunners of such a catastrophe. Earthquakes are so often preceded by gales of wind and storms, that in

certain countries, notably in Central America and the Mississippi valleys, these atmospheric disturbances are regarded as prognostics of a shock.

Upon Nov. 4, 1799, a violent hurricane and thunderstorm preceded the earthquake at Cumana, in Venezuela; the earthquake which destroyed Broussa in 1855 was preceded by a tempest of lightning and hail; the Viège shock in 1865 also occurred during a tremendous thunderstorm, as did the shocks in the Island of St. Thomas in the same year. Many other instances might be cited; but then again the earthquake shock as often happens when the sun is shining, the air clear and still, and the wind balmy and soft.

The fires in the sky, which Pausanias included among the forerunners of the calamity, are still regarded as such in South America, in Peru, in Chili, and Ecuador. The evening before the terrible shock which destroyed the town of Mendoza in a minute, an enormous meteor, of a bluish-red tint, shot through the sky from east to west. The whole population was alarmed, and regarded the phenomenon as the presage of a terrible earthquake. In 1797, just before the Riobamba earthquakes, one of the severest on record, a like phenomenon was seen—there being a regular shower of shooting stars just before the first shock. The Cumana earthquake in 1766 was also preceded by a

shower of luminous meteors. Upon another occasion there was such an abundance of shooting stars above the volcano of Cayambe, near the town of Quito, that the whole mountain seemed



The sky streaked with lightning flashes and meteors. The inhabitants regard them with terror, as presages of an earthquake.

to be on fire, and as this lasted for an hour the inhabitants flocked out to the plain of Ejido, fearing that an earthquake would follow. But such was not the case on that occasion.

It is said, too, that springs either run short or dry up altogether before a great earthquake. Thus at Lisbon the springs dried up before the

shock, and began to flow again after it ; the same phenomenon being observed not only in all districts to which the shock extended, but in the greater part of Germany. So in 1818, when there were so many shocks in central Europe, it was observed that, although the season had been a rainy one, the level of the principal lakes fell several inches. It has been observed, too, that spring water and wells often get very turbid before an earthquake. Thus in 1883, at the time of the catastrophe in Ischia, the water of a spring at Casamicciola got very thick, but became limpid as ever after the shock. As this same spring got very thick again a few weeks afterwards, a fresh shock was apprehended, but did not, fortunately, occur.

It has been thought, too, that most animals have shown signs of fear for some time before a severe shock ; as if their senses, more susceptible and highly-attuned than ours in many respects, enabled them to perceive the underground mutterings of the disturbance before we can catch them. It is well known, as I have said, that most animals are in a state of great fear during an earthquake, but there is no evidence that they are alarmed before the shock takes place ; that is to say, before the premonitory sounds have reached the human ear.

Be this as it may, we are assured that lizards, snakes, rats, mice, and moles emerge from their holes, and rush about in terror before an earthquake shock. At Naples, a few hours before the great shock of 1058 the grasshoppers were observed to swarm from the fields on to the sea-shore, and the fish to come close in to shore in shoals. Early in the morning of October 12, 1855, a quarter of an hour before the violent shock which extended through Lower Egypt, the dogs began to bark, and the donkeys to bray so lugubriously, that they woke up all the inhabitants of Alexandria; and it was the same at Cairo two hours before the shock.

As a rule, the shock is preceded by a rumbling noise, but the interval between them is so brief that people have not time to seek safety in flight. The two come so close together that the second is felt just as the first is being heard. Sometimes the shock is not preceded by any rumbling, while in other cases loud rumblings go on for months together without being followed by any shock. These noises, unaccompanied by a shock though they may be, none the less keep the inhabitants of a district subject to earthquakes in a state of constant alarm, for they never know what is going to follow. This was the case with the mutterings and rumblings at Guanajato, a Mexican

town situated in a mining district, some way from all volcanoes. Alexander von Humboldt relates that these noises began at midnight on the 9th of January, 1784, and lasted more than a month. After rumblings more or less deadened, the underground storm burst with great fury, and one could hear, as it were, the short, sharp flash of the lightning, alternating with the long rolling of distant thunder. The noise ended as it began, that is to say, by degrees, and it was not heard a few miles off. The inhabitants were so alarmed that they fled from the town, leaving large quantities of silver in bars behind them, and only a few of them had hearts stout enough to induce them to return and prevent the brigands from carrying it off. There was not the slightest shock, either upon the surface or in some neighbouring mines, which were nearly 1,600 feet deep.

The measures taken by the authorities, when the panic caused by this underground storm was at its height, were incredibly severe; it being decreed that "any family which attempts to leave the town shall be fined a thousand piasters if rich, and sent to prison for two months if poor. The militia is instructed to give pursuit to all fugitives." The most curious point in connexion with this matter is the self-sufficiency of the municipality, which announced that "it will be able in its

wisdom to say when the danger is imminent, and take measures for enabling the people to fly for refuge. In the meanwhile the processions are to continue." The municipality had provided for everything except for the subsistence of the inhabitants, whom it detained in the city by force. A famine ensued, for a dread of the rumbling noise deterred the dwellers in the higher regions from bringing their corn to market. Humboldt says that no such disturbances had been heard before in Mexico, nor have they since.

But similar phenomena have been observed elsewhere oftener than would be imagined. Thus, in 1822, the inhabitants of the island of Melada, upon the coast of Dalmatia, were alarmed by a series of formidable sounds which came up from under their island, and went on for two years, there having been more than a hundred successive explosions in one night. The inhabitants, who were expecting a terrific earthquake, implored the Austrian Government to provide them with the means of emigrating in a body to some other part of the Empire. But nothing came of all this rumbling noise, except that there was one slight vibration of the soil. Thus we see that these rumbling sounds occur at a distance from any volcano, and that they are not of necessity followed by any shock.

At the same time, in countries where the earthquake is connected with volcanic phenomena, just as effect follows cause, the imminence of an earthquake may sometimes be indicated by means of an ingenious apparatus known as the seismometer, which enables one to observe vibrations which would otherwise escape notice. One of the best of these contrivances is that invented by Signor Palmieri, Professor of Natural History at the Naples University. By the motions of a needle this instrument indicates upon a dial the slightest vibration of the soil over which the needle is suspended, and it also shows the exact direction of the subterranean waves. There are some very ingenious instruments at the Naples University, at the Observatory of Vesuvius, within little more than a mile of the crater, and at the foot of Mount Etna. As the ground in the neighbourhood of these mountains trembles in proportion as the subterranean fire becomes fiercer, and as the seismometer registers most accurately the force and direction of the vibrations, the volcanic eruption, and the earthquake shock accompanying it have often been foretold. More often than not, however, the earthquake has occurred too suddenly to admit of the inhabitants being forewarned.

We have not, therefore, any known means of

foretelling an earthquake. Other calamities give some warning note : the volcano roars before its lava flood begins to flow ; the waters of a river rise gradually before they overflow ; the hurricane gathers and drives the black clouds in front of it before bursting in full fury upon us ; but there is nothing to tell of the coming of an earthquake, neither in the heaven above, nor on the earth beneath, nor in the waters under the earth.

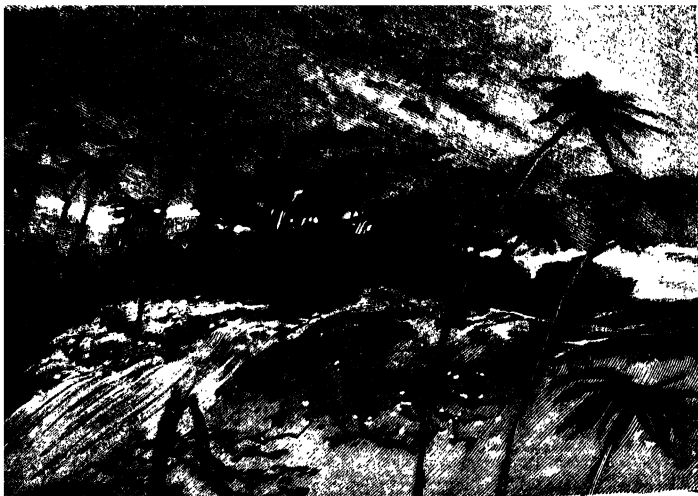
THE CATASTROPHE ITSELF.

I.—THE SHOCKS.

Difficulty of observing the motions of the soil during severe Earthquakes.—Three different motions.—Undulations and Earthquake Shocks in Calabria in 1783.—Motions of the ground which destroyed the town of Riobamba, in Ecuador.—Duration of shocks.

THE least dangerous earthquakes are those which the inhabitants of South America call *temblores*, and which are not unlike the shivering of the human body. Very frequent in the countries subject to more violent shocks, they sometimes produce a sort of buzzing noise; while at others they emit a sound like that of a distant explosion. This quivering of the earth's crust is like that which takes place around craters full of boiling lava. They often occur after a severe earthquake, and last for a long time after the catastrophe of which they are the dim echo. Shocks of this kind only occur in countries remote from the centres of disturbance, and in which the subterranean wave spends its final energies. They have often been felt in France, Germany, and Lombardy after some violent shock, the centre of which was in Switzerland.

These shocks are rarely dangerous. At the most a few light articles of furniture are upset, a few walls cracked, and a few slates shaken off the roof; and so, in South America, a marked distinction is drawn between these *temblores* and the



Forest agitated by earthquake shocks in Central America.

severe shocks called *terremotos*, which are the real earthquakes; each shock dealing out ruin.

It is not easy to say exactly how the ground trembles during these terrible convulsions, when the mind of even the bravest of men is sorely disturbed. One cannot be expected to watch with critical eye the motions of the ground which is

yawning as if to swallow up the people whose heart-rending cries are blended with the subterranean roar. It has been my misfortune to witness several of these catastrophes, but, overtaken upon each occasion by the suddenness of the shock, I have never been able, amid the general terror, to notice accurately the direction of the first shocks. When the emotion which they must inevitably create has passed away, I have, when the earthquake has lasted, occasionally been able to realize where I was, and take note of the dread phenomenon.

Let me remark that what moves the man accustomed to study nature, when the subterranean shock occurs, is not the fear of danger so much as the strangeness and the sinister majesty of the phenomenon. When, to use the expression of Alexander von Humboldt, the earth has been shaken to her foundations, one is awakened from a dream, feeling that one has been misled by the apparent calm of nature. Such is the impression produced by the first shock, but if the shocks are repeated, and go on for several days, the feeling of uneasiness disappears, and one can then observe without hindrance the phases of the phenomenon while the subterranean thunder is growling and the soil trembling.

There are three different motions of the soil :

vertical shocks, that is to say, a rapid succession of shocks from below to above ; secondly, a horizontal or lateral oscillation ; and, lastly, the revolving or gyratory shocks. It is in the centre of the disturbance, at the spot where the subterranean shocks are most violent, that the vertical motion is chiefly felt. The further one recedes from this central point, the more oblique become the motions of the soil, until they ultimately assume a horizontal direction. The vertical motions from below to above generally produce the effect of a mine explosion. A shock of this kind was felt in Spain on the 21st of March, 1829, and it brought to the ground more than 3,500 houses in the province of Murcia alone. The first shock of the Riobamba earthquake in 1797 threw up on to a hill more than 300 feet high all the bodies buried in a cemetery some distance off. The surface of the ground then undulated up and down, the oscillations bringing out into the roadway several persons who were standing in the choir of a church at a level of nearly twenty feet above the street.

Hamilton, who was ambassador of England at Naples at the time of the great earthquake which did so much damage in Calabria towards the beginning of 1883, says, that during the first few shocks houses were torn violently up from their

foundations, and that mountains rose and fell like the waves of the sea. During this earthquake houses were moved from a higher to a lower level without sustaining any damage, while other houses were carried higher up in the same way. So, too, many persons found themselves landed upon some eminence, when they thought that the ground had been sinking under them ; while others, who in their alarm had climbed up trees, found themselves quietly deposited upon the ground, when they thought that the ground was rising all around them. These facts are very curious, and can only be explained as being due to some optical illusion, it being probable that those who thought they saw the ground rising up to them were falling at the same time as the ground upon which they stood, and that those who thought they saw the ground sink beneath them were lifted above the ground, which for an instant remained motionless. Just in the same way as it may seem to us that the lift is stationary and the objects around it are descending, whereas it is we who are ascending ; or, upon the other hand, that walls are raising themselves around us, instead of which we are running down in the lift.

The long subterranean undulations which extend horizontally from the centre of the disturbance, like the waves of the sea, lose in intensity

and proportion as they recede from the centre ; but when near to this centre they are scarcely less violent than the abrupt and vertical shocks with which they are often, indeed, identical.

During the Calabrian earthquake trees were seen to bend and recover themselves, their branches touching the ground, and their tops coming into such violent contact with the soil that they were broken off short ; while, in a long avenue, the trees undulated in such regular succession that one could follow the progress of the subterranean wave just as one can that of a submarine wave sweeping into a harbour, and raising upon its crest vessel after vessel as it rolls shoreward. At Messina, during this earthquake of February, 1783, the houses nearest to the sea fell in first, and then those further inland, as the undulation, which had started from the Calabrian coast, swept onward. In 1811, during the violent shocks in the Valley of the Mississippi, vast forests, with their trees of gigantic size, were seen to bend and wave, as if assailed by a furious hurricane.

The rotary or turning movement is the rarest, and it has never been observed directly, its occasional occurrence being conjectured from the effects produced by certain earthquakes. After the Riobamba earthquake in 1797, walls were

turned round without being thrown down, garden walks which were straight have been made crooked, and fields covered with vegetation have been found one upon the top of another. At Quintero, in Chili, three large palm trees were observed to have got entwined, the one round the other, like so many willow branches, having first cleared a small space around their trunks. During the Calabrian earthquake of 1783 the pedestals of two obelisks standing in front of a monastery at San Stefano del Bosco, remained as they were, while the obelisks themselves were twisted several inches out of the perpendicular. It is said, too, that during the shock which occurred in the island of Majorca in 1851, the base of a tower was caught in the rotary horizontal motion, and that it revolved around its axis at about 60 degrees, while the upper part of the tower retained its original position. During the earthquake in Viège (Switzerland), in 1855, the steeple of Greechen was completely twisted.

It sometimes happens, too, that the earthquakes in several opposite directions at once, the surface whirling round at the same time that it heaves up and down and horizontally. The Jamaica earthquake of 1692 offers a very remarkable instance of this. At Port Royal the oscillations of the soil were so rapid that the



INHABITANTS OF RIOBAMBA DISPUTING POSSESSION OF FURNITURE AFTER
THE EARTHQUAKE.

whole surface of the earth seemed to be in a state of liquefaction ; articles of furniture, etc., being flung about promiscuously with the inhabitants, who, falling in all directions, were badly bruised. Some of them, it is said, were thrown from the centre of the town into the port, whence they were able to extricate themselves by swimming.

When Humboldt sketched the ruins of Riobamba, three years after its destruction in February, 1797, he found nothing but a vast heap of stones, with eight or ten feet of rubbish ; and yet the town had possessed churches, cloisters, and houses several stories high. He was shown a place to which the furniture of a dwelling house some distance off had been carried, and several law-suits were instituted with regard to the ownership of furniture which had been carried to a distance in the same way.

It is patent, as Humboldt remarks, that when the ground slips in this way there is a sort of penetration of the superficial strata. The fields with their growing crops which are heaped one upon the other, the straight paths which become crooked, and the houses which change places, testify to a general movement of translation. Beneath the influence of the subterranean waves, which are alternately from below to above, then

horizontal, and then circular, the soil is put in motion like some liquid which is being violently shaken in all directions. Nothing can resist such a motion as this, and all edifices standing upon the surface are overturned and crumble to pieces. It is scarcely possible to give the exact duration of the commotions which lead to such great disasters; but it may be said broadly that most shocks do not last more than a few seconds, and that an oscillation has rarely been known to exceed a minute in duration.

Upon the 18th of August, 1853, an earthquake utterly destroyed the town of Thebes in ten seconds; while that of 1812, which annihilated the town of Caracas, the capital of Venezuela, lasted only three seconds. A first shock set the church bells ringing, lasting five seconds; and this was followed by a second, which lasted about the same time, and brought in the roofs of the houses; while, in the twinkling of an eye, and before any one had time to think of flight, a third shock transformed this opulent city into a heap of ruins. Upon the other hand, the first and most severe shock of the Calabrian earthquake in 1783, is said to have lasted nearly a minute; while the earthquake shocks in the island of Guadeloupe in 1843 lasted over a minute.

The longest shocks upon record are those which

occurred during the earthquake of 1867, in the island of St. Thomas. At first the oscillations were numerous and so quick that for ten minutes it was scarcely possible to take account of the interval which divided them, though it is beyond question that several of these violent shocks lasted eighty seconds. The worst shocks are not always the longest, and it may even be admitted that as a rule their duration is in inverse proportion to their force. In an instant they completely reverse the appearance of a country, and complete their sinister work.

An earthquake rarely consists of a single shock. As a rule, the ground is moved by a series of oscillations, among which there is invariably one, more severe than the rest, which does the mischief. It is easy, therefore, to understand how an earthquake can last several hours, weeks, or even months, during which time hundreds of pulsations will be felt. During the San Salvador earthquake in 1856 it is said that there were 118 shocks, and during the fortnight following the catastrophe of 1867 in the island of St. Thomas, there were twenty-eight shocks each day. Shocks at less frequent intervals were felt for another two months; and the same was the case after the dreadful earthquake which destroyed Lisbon. A sharp shock was felt in the island of Hawaii, in the beginning of March,

1868, a short time before the eruption of the crater of the Maunaloa volcano, and after this first shock the ground continued to oscillate for the remainder of the year ; the trepidations being so numerous that the attempt to count them was abandoned. There were as many as 2,000 in the month of March alone. After the violent shock in the Valais upon the 25th of July, 1855, the ground was in a state of constant disturbance for six months ; while, after the earthquake shock which destroyed the town of Basle in 1356, the ground was in a state of trepidation for fully a year.

II.—THE UNDERGROUND NOISE.

Earthquakes are not always preceded by underground noises.—
Nature and Explanation of the latter.

THESE terrible shocks are, as we have said, accompanied by a loud underground noise, which is generally heard a few seconds before the shock, and lasts without intermission the whole time.

It is generally believed at Cumana, a town upon the coast of Venezuela, that the most destructive earthquakes are preceded by very slight oscillations, and by a rumbling sound, which persons accustomed to these phenomena have no difficulty in detecting. At this solemn moment the piteous

cries of "Misericordia, tembla, tembla!" are heard in all directions, and it is very rare that the natives are mistaken in their impressions. Sometimes, though not often, the underground noise is heard after the shock. Thus the shocks which in



A traveller listening to underground noises.

1861 annihilated the town of Mendoza, one of the most flourishing in South America, were not preceded by any noise, but afterwards it burst forth with extraordinary violence. More rarely still, the earthquake wreaks its fury without any sound either before, at the time, or afterwards, the whole process of destruction being silent. The

Riobamba earthquake, which in two minutes destroyed 200,000 persons, was a case in point. A tremendous detonation, still designated by the words *el gran ruido*, was heard eighteen or twenty minutes afterwards in the two towns of Quito and Ibarra, but not at the scene of the catastrophe itself. The underground noise which accompanies the severe shocks is always very alarming, but it is only after the catastrophe that one can fairly estimate the intensity and nature of this noise, which is very varied in character. During the severe shocks it is no easy matter to follow attentively the gradations of the underground noise, owing to the heart-rending scenes which are being enacted, and to the emotion which even the calmest must instinctively feel, while they are in progress. So that when after the disaster one endeavours to compare these mighty underground rumblings with other and more familiar sounds, the proper terms of comparison are wanting, and those which one is compelled to employ are insufficient to express what one has heard.

Thus, speaking from my own experience, I should be inclined to say that the subterranean noise is often like the rolling of thunder after the first crack. That is as near a description as I can give of what I have heard, and yet it would fail to convey an idea of how terrible this subterranean

voice is. It is something more and something less, being less sonorous, less abrupt, and less tumultuous than the thunder of the air ; but it is more violent, more sustained, more penetrating, and more lugubrious. At other times, a long groan appears to rise up out of the bosom of the earth, especially before the first shock ; while it sometimes sounds like the beating of the wings of mighty birds, or the hum of a swarm of bees, or a discharge of artillery, or the cracking of rocks in underground caverns, or the dull thud of a heavily-loaded waggon, or the hissing and howling of a hurricane. How are these various sounds, so lugubrious and so terrible, to be accounted for ? It is evident that they are due to an equally varied series of phenomena, going on within the bosom of the earth, to the lava of the abysses which is seething and beating against the upper strata ; to subterranean landslips, and to the disturbances which they cause ; to the overflow of the waters of lakes and streams beneath the action of the shock ; to the immense currents of gas and air which are engulfed in the caverns and fissures, giving rise to these subterranean hurricanes. All these sounds are re-echoing within the earth's crust, and as they travel athwart the rocky strata which lie between them and the surface, scatter terror and desolation among those who dwell upon the latter.

III.—GULFS AND CREVICES.

Earthquakes create deep fissures in the soil.—Crevice
suddenly formed.

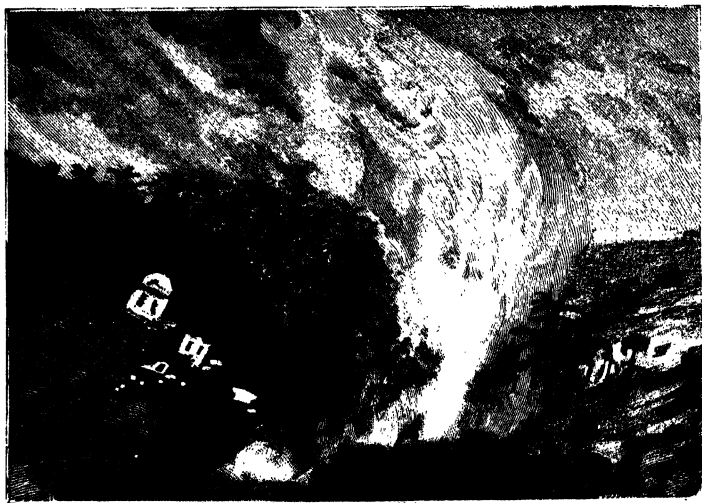
DURING the shocks the earth opens, the surface of the ground is broken up, and large crevices appear. Sometimes they take the form of long and narrow cracks, while at other times they form a yawning gulf. They are often to be met with in great numbers in the direction of the shocks which have brought them about, though they sometimes cross each other and break off into lateral branches.

The Calabrian earthquake is specially remarkable in this respect, as a crevice, several yards in width, appeared at the base of the granite mountain of Polistena for a distance of twenty or five-and-twenty miles.

These crevices are very dangerous, and do terrible mischief, swallowing up human beings, houses, and forests, which they crush as between gigantic jaws when they close up again. After the first shock of the Lisbon earthquake an immense crowd took refuge upon the broad marble quay which runs along the shore, so as not to be buried beneath the falling buildings, but an enormous crevice was formed after several violent

shocks, and the whole quay was engulfed in the waters.

During the Calabrian earthquake in 1783 most of the houses at Terranova and Oppido disappeared without leaving the least trace, and the



Village, forest, and fields disappearing in an abyss.

sides of the crevice, as it closed upon the engulfed buildings, shut in so tightly that when the soil was cleared there remained only a shapeless mass of brickwork and timber.

During the violent shocks which occurred in Spain during December, 1884, some enormous crevices were formed ; and houses were swallowed

up in that which ran through the village of Guevejar ; while, further on, a church and steeple disappeared within this yawning gulf, which was nearly two miles in length.

There were some immense cracks in the soil during the severe earthquake shocks in Jamaica (1692), and as they opened up they engulfed many persons, whose bodies, horribly mutilated, were thrown up when the ground, opening afresh, discharged a quantity of subterranean water. A man named Louis Gelday, who lived in the outskirts of Port Royal, was swallowed up in one of these crevices, and was afterwards thrown up alive by a second shock, and hurled into the sea. He was able to swim to shore, and lived forty years afterwards to tell the tale of his wonderful escape, as may be gathered from the inscription upon his tomb at Port Royal.

When the earthquake at Lisbon occurred the effects of it extended to the African coast, and several deep crevices were formed in the neighbourhood of the capital of Morocco ; while an oasis, situated only a few miles off that city, was swallowed up, together with all its villages and inhabitants, in a gulf, which closed again instantaneously ; more than ten thousand Arabs perishing in the catastrophe.

During the earthquake which occurred upon the

tableland of Quito in 1797 several cracks opened and closed in such a way that some people were able to escape by stretching out both arms. Many persons on horseback and mules laden with merchandise were swallowed up; while others escaped by moving rapidly backward. Alexander von Humboldt relates, that on this occasion many houses sunk into the earth with so little damage that the occupants, safe from all injury, were able to open the inside doors, and await their deliverance for two whole days. They went from room to room, with lighted torches to see their way; cooked their food, and discussed with one another the chances of their being rescued.

Among the most curious effects of earthquakes must be reckoned the deep wells which open instantaneously, and which are found to be full of water or sand to their mouth, the latter being, as a rule, round and convex, and nearly always surrounded with a layer of slime. The most celebrated of these basins, in respect to number, dimensions, and symmetry, are those at Rosarno, in Calabria, which had their origin in the two earthquakes of 1783. Immediately after the shock most of these wells had the shape of a funnel inside, and looked like small ponds, some filled with water and others with sand which came right up to the surface. This fact might possibly

be explained by the large quantity of earthy substances forced up to the surface, which, accumulating, produced an obstacle which the water



Circular crevices and wells formed during an earthquake.

raised from the depths of the globe could not surmount.

The Wallachian earthquake in 1838 lasted from the 11th to the 23rd of January, and gave rise to many large crevices, one of which, near Beltschuk,

communicated with a number of gulfs, from which were emitted sand and water. During the Broussa earthquake in 1855 a farm of nearly ten acres disappeared, and the owner, who was some distance off, saw his house and land gradually engulfed beneath the surface of the earth, and a vast column of water bubble up upon the site.

IV.—SPRINGS, LAKES, AND RIVERS.

Rivers suddenly change their course.—Movement of Lakes.—
Modification of springs.

EARTHQUAKES sometimes occasion a general disturbance in the water system of the district. While a severe shock is in progress rivers and lakes undulate violently, and the level of their waters is either raised or depressed all at once.

At times the waters of a stream are precipitated in a fresh direction, impelled by the underground shock, which, after having destroyed their former bed, has made a fresh one for them, by either raising or lowering, as the case may be, the ground around them.

In 1546, after a violent earthquake which destroyed the cities of Sichem and Rama, the waters of the Jordan first began to fall, and then dis-

appeared suddenly, the bed of the stream remaining dry for two days and two nights, but upon the third day the stream again filled.

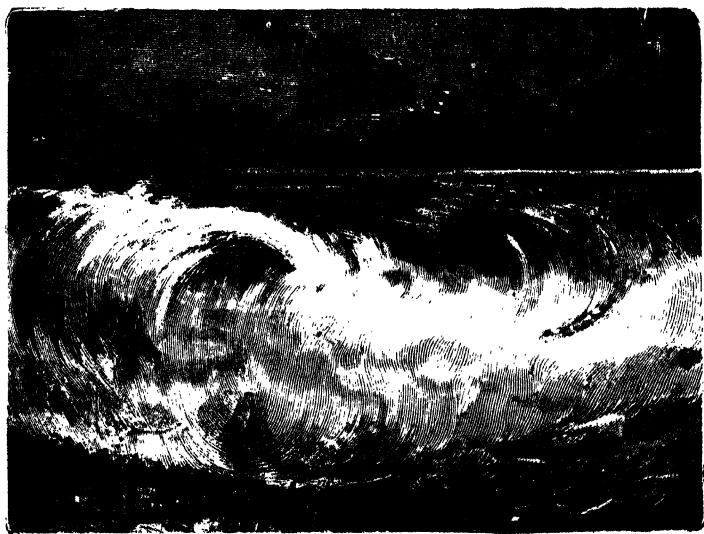
During the Andalusian earthquake in 1884 the river Cogollos suddenly altered its course, and all the streams and rivulets around the village of Guevjar disappeared, while the bed of the river Almachar, in the same district, was riven asunder, and its waters inundated the surrounding country, which it was no longer possible to irrigate.

At times, the water of rivers and large lakes rises like a mountain to a great altitude, and in falling back submerges the surrounding country. The fall of this mass of water is always accompanied by a terrible crash, and it buries everything which comes in its way. Thus upon the 26th of August, 1856, during a violent underground earthquake in Honduras, a lake several leagues in extent suddenly overflowed, and did more damage than the earthquake itself.

The underground scourge also has a very preponderating influence upon the vast and peaceful system of springs, the beneficent action of which animates and maintains organic life upon the surface of the planet. An earthquake shock will cause some springs to dry up, and others to increase in volume, while in some cases fresh springs are brought into play. Thus in Greece,

which has suffered more from earthquake than any other country in Europe, a great number of springs, some still in existence, others since exhausted, have been born in the midst of earthquakes.

As a rule, an underground shock disturbs the



Violent upheaval of the waters of a river during earthquake shocks.

water of springs and wells, especially of artesian wells. M. Hervé-Mangon has ascertained by a series of very careful observations that the water of the artesian well at Passy (Paris), became loaded with sediment after each of the many earthquake shocks which occurred in Western Europe during the years 1861 and 1862.

A great many case are also given in which the temperature of thermal springs has been decreased or raised during an earthquake. In August, 1854, when an earthquake occurred in the Pyrenees, the temperature of a spring at Barèges rose from 64 to 84 degrees Fahrenheit, while the outflow rose from 1400 to 3200 gallons a day. During an earthquake in the Canton de Valais in 1856 the temperature of the springs at Louèche increased very suddenly. The same was the case with the springs of Andalusia during the earthquake of 1884 ; and many new springs have come into existence, among others one at Santa-Cruz. The mineral waters of Alhama are now much more abundant than they were before the destruction of that city, and their chemical composition and temperature have changed. Before the shock they had a temperature of 118 degrees Fahrenheit, and were saline in character. Since then they have become impregnated with sulphur, and have nearly doubled in temperature.

Facts of a similar kind have been observed in all the districts subject to earthquakes, and it has often been remarked that the chemical springs of Sarcon, in Persia, situated at an altitude of about 5,600 feet above the level of the sea, upon the road from Ardebil to Tabriz, are affected by the earthquake disturbances, which occur about every

two years. In October, 1848, the earthquake undulations were so violent that the inhabitants of Ardebil were compelled to fly from that town and the springs, which as a rule are about 110 degrees Fahrenheit, reached boiling point, and so remained all the month.

V.—ERUPTIONS OF LAVA, FLAMES, AND EFFLUVIA.

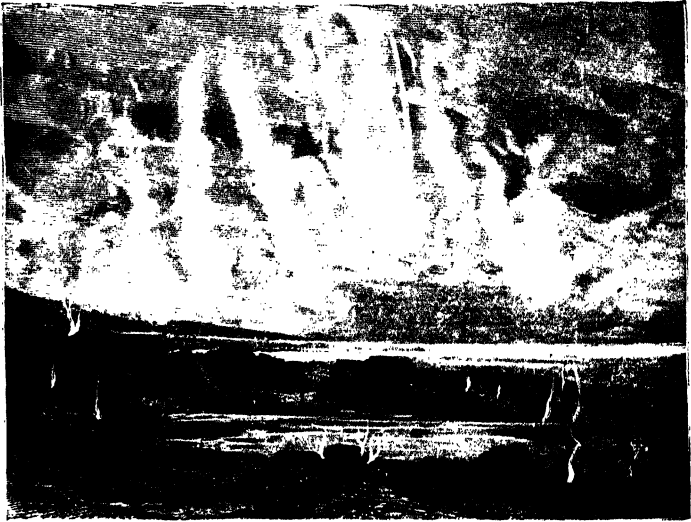
Streams of mud descend from the mountains and submerge the plains.—Catastrophe upon the upper plateau of Riobamba.—Burning gases issue from the ground.—Exhalations injurious to plants and animals.

It is not only jets of water and sand which are thrown up from the bowels of the earth at these times, but mud, vapour, gas, black smoke, and even flames of fire are emitted. When a severe shock occurred upon the lofty tableland of Ecuador in June, 1698, and destroyed the small town of Latacunga, and several other villages, as far as the town of Ambato, the volcano of Carihuairazo, a mountain 16,700 feet high, fell in at places, as did other lofty mountains. The result was that severe inundations followed, if the term can be applied to liquid mud, which gradually formed itself into streams and rivulets, traces of which were visible half a century later, when La Condamine, Bouguer, and Godien explored this

region. Whole fields, with the trees planted in them, were moved to a distance of many miles ; and at Latacunga itself whole families were buried under one roof, not a single house being spared, and nearly all the mischief was wrought by the first shock.

During the Riobamba catastrophe in 1797 the volcanoes near the unhappy city, the Cotopaxi, the Sangay, and many others, were not in a state of eruption at all. But one of them, the Tunguragua, was riven asunder, and one portion of this mountain, which rises to an altitude of over 16,000 feet, between Riobamba and Quito, fell suddenly in with the forests upon its slopes. Streams of viscous mud issued from the yawning abyss, and rolled down into the valley with such violence and in such vast quantities that they caused the death of the whole population, composed of 40,000 Indians, and that a single one of these torrents filled a ravine about a thousand feet wide by seven hundred deep, which separated the Tunguragua from another mountain. The stream of liquid mud did not emerge from this enormous chasm alone, but from crevices which opened out throughout the whole district. The natives called this muddy mixture of water, coal, and silex, "moya," and after having covered the whole district with a thick deposit, it became solidified

into countless mounds with the shape of regular cones. Very often, too, there is an emanation of poisonous gas and vapour, and during the Algerian earthquake in 1856, which lasted several weeks, the atmosphere was impregnated with



Flames and effluvia issuing suddenly from the ground.

sulphurous vapours, and phosphorescent effluvia were visible upon the ground, not, it is true, by day, but when the sun went down. For several nights in succession lights like that of the will-o'-the-wisp were seen moving about upon the valleys and hillsides, notably upon the mountains of Oued-Missia.

At other times these gases burst out from the ground, just as the subterranean convulsion occurs. In that case a bright flame issues forth from the bowels of the earth, flashes for a moment, and then passes away like lightning. During the earthquake in question a French officer, who was with his detachment upon the slope of a hill near Djidjelli, suddenly saw blue flames shoot up from the earth to an altitude of sixteen feet, following each in rapid jets, and as suddenly disappearing. This singular phenomenon lasted nearly an hour. At Cumana, half an hour before the shock of December 14th, 1797, a strong smell of sulphur was perceived, and when the shock occurred flames were seen upon the banks of the river Manzanares, upon which the town is built, and also in the gulf of Canaco. So, in Ecuador, during the terrible earthquake of 1736, an immense blue flame shot up from the bottom of the lake, forcing its way through the water. During the Lisbon earthquake in 1755, flames and columns of smoke shot out from a crevice in the rock, and it was remarked that the flames were projected with more violence and intensity according as the subterranean noise was louder.

An immense quantity of carbonic acid was emitted when the earthquake shock occurred in New Granada in 1827, and this gas suffocated a

great many animals which lived in the caverns. The fear manifested, both before and during the shock, by the animals which inhabit the caves and holes in the rocks, such as lizards, snakes, rats, etc., is probably due to the action of these underground effluvia, for it is easy to understand that these animals, crawling on the surface of the ground, are the first to feel the effects of these noxious gases, which are too heavy to rise into the air.

At the same time, I will not take it upon me to say whether these animals, so close to the surface of the ground, hear the subterranean rumblings before others, or whether their fear is caused by the sensation of these gaseous emanations. During his sojourn in Ecuador, Humboldt noticed in the interior of the country a fact which is connected with this kind of phenomenon, and which has been remarked more than once, viz., that the herbs which cover the savannahs of the Tucuman become poisonous, and that the cattle seem to be stupefied by the gas which comes out of the ground.

VI.—EXTENT OF THE DISTURBANCE.

Undulation of the water and terrestrial undulations. — Nothing arrests the spread of the destroyer.—Earthquakes which have extended to a great part of the earth's surface.

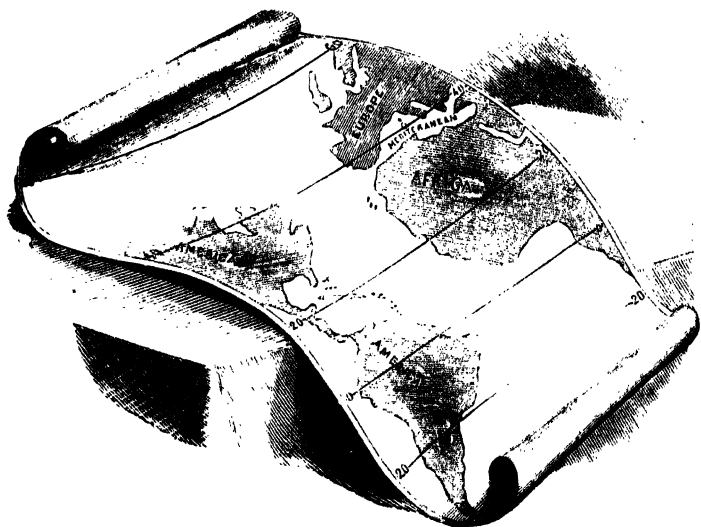
THE space affected by severe shocks is sometimes limited to a few miles, but for the most part the surface thus disturbed embraces several hundreds, at times even thousands, of miles. Nothing arrests the scourge, which, forcing its way over mountain, stream, and ocean depths, finally disturbs an immense zone.

From the centre of the disturbance, that is to say, from the spot where the phenomenon starts, the shocks, at first vertical, tumultuous, and violent, gradually become more oblique, and are transformed into subterranean undulations, which extend towards the interior of the earth, and die away far from the centre of the catastrophe. The undulating phenomenon which thus occurs in the subterranean rocky strata is analogous to that observed when a stone is thrown into the water : there is a great disturbance at the spot itself, the water rising and falling violently, but the rings spread out, and become fainter as they recede from the centre of the disturbance.

In November, 1827, a shock occurred upon the

soil of New Granada, and covered a surface nearly twice as great as that of France, destroying the town of Popayan and most of the towns situated between it and Bogota, the capital.

In 1856 the subterranean undulations which



Map showing the sea and continents disturbed in 1755.

started from Asia Minor extended to the whole of the Mediterranean region, and the shocks of this earthquake, the last quiverings of which died out in Saxony, were felt not only in all the islands of the Mediterranean, between the island of Cyprus and Sicily, but upon the Dalmatian coast, throughout Turkey, and even in Egypt.

The Chili earthquake in July, 1794, affected an area of fifty thousand square leagues, and the shock of the island of St. Thomas in November, 1867, extended to the Indian ocean, from the gulf of Mexico, and the shores of Florida, to the coast of South America ; so that the area of the disturbance may be estimated at 250,000 square leagues.

The Lisbon earthquake in 1755 extended over a surface of the globe four times greater than that of Europe, affecting not only Portugal but nearly all Europe, the north of Africa, where it destroyed the cities of Fez and Mesquinez in Morocco, with 15,000 persons ; the coasts of Greenland ; the isle of Madeira ; and the West Indies, nearly four thousand miles away.

THE UPHEAVAL, SUBSIDENCE, AND SLOW UNDULATION OF THE SOIL.

I.

The coasts of Chili upheaved by underground shocks.—A territory suddenly upheaved in New Zealand.

EARTHQUAKES sometimes give rise to considerable elevation of isolated places, and even of whole districts. The fact is certain, easy though it is to make a mistake as to differences of level, especially in regard to the increased elevation of coast, and it has often been found that land which was thought to have been raised by subterranean force, had not in reality altered its level.

But elevation of the ground has taken place at times, and, after the earthquake of Cumana in 1766, Humboldt relates that the point of Dalgadi, in the gulf of Cariaco, was raised to a marked extent, and that a shoal was formed near the village of Maturin, this being doubtless due to the action of the subterranean forces, which had displaced and upheaved the bed of the river Manzanares.

There can be no doubt that the soil of Chili was

raised in the neighbourhood of the town of Concepcion after the earthquake of 1750. The town was destroyed upon the 24th of May, and the sea, after having invaded the city, carried away with it as it receded the ruins which it had submerged. The old port was obstructed, and those of the inhabitants who survived built a new town fifty miles away from the old one. A certain extent of land, now well above the level of the sea, was covered, before the shock occurred, with a sheet of water twenty-five or thirty feet deep. It is clear, therefore, that there was in this case a sudden upheaval of the soil, and since then vessels have not been able to come within eight miles of the old port. In fact, we may say that the coast has risen at least twenty-four feet here.

Similar facts were noticed upon the same coast after the earthquake of 1822. The shocks lasted from the 19th of November to the end of September in the next year, following each other, some days at an interval of five minutes. Their effects were felt all along the coast, from Lima to Concepcion, a distance of more than 600 leagues, and eastward as far as the principal chain of the Cordilleras. Near Valparaiso and Quintero water mixed with sand and mud escaped from the crevices of the soil; and the valley Vinna à la Mar was covered with small cones of muddy sand.

Lyell, in his "*Principles of Geology*," tells us that the granite rocks which overhang Lake Quintero, and the granite mountains which extend along the coast for a distance of a hundred miles, had fissures five miles in length, and that oyster-beds were discovered far inland. It is said that the coast of Valparaiso was raised three feet, and Meyen, who visited the town of Valparaiso in 1831, asserts that he discovered the remains of marine monsters upon the rocks which had risen from out of the waters.

The same phenomena of the elevation of the soil also occurred on the 21st of February, 1835, soon after the eruption of the volcano of Coseguina. An undulating movement was felt throughout the continent, from Copiapo to Chiloé, and from Mendoza to Juan Fernandez, three hundred miles from the coast. Upon this occasion it is said that the soil rose four or five feet, and then subsided again about three feet.

When Mrs. Graham gave it as her opinion that all the coast had been upheaved by the earthquake of Nov. 19th, 1822, the effect of which was so widespread, it was accepted as probable by most geologists, but not by all. Cuning, the well-known conchologist, happened to be on the spot at the time, and he said that he had not noticed anything unusual. According to him, the water

reached the same point at high tide, and he attributed the quantity of shells to the irregular motions of the sea brought about by the frequent earthquakes.

Soon after the sharp earthquakes of 1835 an American expedition, under the command of Charles Wilks, the well-known sailor who afterwards commanded the American scientific expedition in the Southern Sea, and studied the volcano of Maunaloa, investigated this point very closely. He says: "The versions given by the inhabitants are so contradictory that it is impossible to draw any satisfactory conclusion from them. The subsidence of the waters in the gulf, if it actually takes place, is only temporary, and the naturalists of our expedition have failed to notice any evidence of the slightest upheaval."

Whatever doubt there may be as to the elevation of the coasts of Chili in 1835 there can be none as to the following fact.

On the 23rd of January, 1855, a violent earthquake occurred in New Zealand, the area of land and water to which it extended being estimated at 300 square miles. In the neighbourhood of Wellington, an area measuring 4,600 English miles, was raised in level by from one to nine feet.

11.

Subsidence of the Valley of St. Eufemia.—Disappearance of the Town.—Great disturbance of the territory of Cutch, in India.—How the Japanese Lake of Biva was formed.

THE crevices and cracks in the ground which often occur after an earthquake must not be confused with the sudden subsidence of the earth's surface which sometimes takes place during a severe shock. In the higher valleys, and in mountainous regions, this collapse of the soil is sometimes accompanied by the falling in of rocks and hills, and even by the downfall of a lofty mountain, and it invariably happens that a sheet of water springs up in the hollow thus produced. After the earthquake of March 27th, 1638, which destroyed two hundred villages in Calabria, the valley in which the town of St. Eufemia was situated fell in. The town was swallowed up in the yawning gulf, and the surrounding hills also collapsed, the chasm which entombed them all being then covered with water.

During the terrible earthquake which ravaged the island of Jamaica in 1692 a property of about 2,500 acres, just outside the town of Port Royal, and in full cultivation, subsided into the sea, and was engulfed in half-a-minute of time. In the

town itself a whole ward was suddenly engulfed, and as the ground sank all at the same level, the buildings were not overturned, but for weeks after the chimneys of the houses might be seen just upon a level with the water, like the masts of the vessels which had sunk at the same time.

During more than one of the earthquakes which have disturbed South America sudden and considerable subsidences of the soil have occurred. Thus, on the 20th of January, 1834, when several shocks partially destroyed Santiago, the capital of Chili, a tongue of land upon the coast which was seven miles long by five broad suddenly disappeared, together with the forest growing upon it. A curious sight was visible upon the same day at Bondionella, for while part of the soil subsided, and pools of water appeared in the depressions, other parts of the soil were lifted to a higher level.

During the earthquake which ravaged Peru in 1786, and destroyed the town of Lima, part of the coast near Callao subsided and formed a fresh gulf.

Then there was the great subterranean disturbance which in 1819 completely changed the physiognomy of the vast tract of land which borders upon the Gulf of Cutch, at the mouth of the Indus. While part of this territory known as

the Runn was subsiding over an area of many square leagues, an immense upheaval occurred across an ancient mouth of the Indus. This upheaval formed a rampart three or four miles long, and 160 feet broad ; and this rampart, which still exists to protect the inhabitants from an inundation of the sea, is called by them the Allah Bund, or, wall of God.

According to an ancient Japanese tradition, an earthquake occurred in the Island of Nipon in the year 286 B.C., when flames issued from the earth, and a tract of country sixty miles in circumference was raised to a prodigious height. This was the volcano of Fusi-Yama, the holy mountain, the tutelary divinity of Japan, which was erecting its enormous body, and which in the space of a single night reared its forehead to an altitude of 12,258 feet. At the same minute, and at a great distance from the scene, an immense plain, shut in by lofty mountains, was violently shaken and suddenly fell in, with the forests, towns and villages upon its surface. No sooner had the valley subsided than the area which it occupied was filled with water and became transformed into a lake 35 miles long by 10 broad. Such at least is the origin attributed by the Japanese to Lake Biva, the blue waters and beautiful shores of which remind one of the Lake of Geneva.

III.

Destruction of Sodom and Gomorrah.—The story of Lot's wife.—
Aspect of the region.—The Dead Sea.—The Jordan.

THE earthquake which destroyed Sodom and Gomorrah is not only one of the oldest upon record, but one of the most remarkable. It was accompanied by a volcanic eruption, it upheaved a district of several hundred square leagues, and caused the subsidence of a tract of land not less extensive, altering the whole water system and the levels of the soil.

The south of Palestine contained a splendid valley dotted with forests and flourishing cities. This was the valley of Siddim, in which reigned the confederate sovereigns of Sodom, Gomorrah, Admah, Zeboiim and Zoar. They had joined forces to resist the attack of the King of the Elamites, and they had just lost the decisive battle of the campaign when the catastrophe which destroyed the five cities and spread desolation in the flourishing valley took place.

As the sun arose, the ground trembled and opened, red hot stones and burning cinders, which fell like a storm of fire upon the surrounding country, being emitted from the yawning chasm.

In a few words, the Bible relates the dread



DESTRUCTION OF SODOM.

event : " The Lord rained upon Sodom and upon Gomorrah brimstone and fire from the Lord out of Heaven, and He overthrew those cities, and all the plain, and all the inhabitants of the cities, and that which grew upon the ground. And Abraham gat up early in the morning, to the place where he stood before the Lord : and he looked towards Sodom and Gomorrah, and towards all the land of the plain, and behold, and lo, the smoke of the country went up as the smoke of a furnace."

Nothing could be more succinct or terse than this description of the catastrophe.

The episode of Lot's wife being turned into a pillar of salt quite harmonizes with the event thus described, for of all the substances generated in the volcanic furnaces none is met with in such large quantities as salt. The moist and burning cinders which shoot forth like a shower of fire from the burning craters are strongly impregnated with this substance, which, after the water in the cinders has evaporated, forms a thick deposit around the volcanoes. Doubtless, the ashes emitted from the bowels of the earth after the catastrophe of Palestine were saturated with salt, for the district itself is covered with it, and one walks upon a thick stratum of friable salt, which crunches beneath the foot and extends as far as

the eye can reach, like the sand in the desert. If upon the day of the catastrophe a woman was overtaken while in flight by a cloud of ashes and enveloped in the shower of burning and saline ashes, her body would have presented the appearance of a pillar of salt, when, after the eruption, the saline substance had become crystallized.

This was a sudden volcanic eruption like that which in the year 79 destroyed in one night the cities of Herculaneum and Pompeii. At the time of the convulsion in Palestine, while clouds of ashes were emitted from the yawning abyss and fell in fiery showers upon the ground, a vast tract of country, comprising the five cities and some land to the south of them, was violently shaken and overturned.

Of the valleys watered by the Jordan, that of Siddim was the largest and most populous. All the southern part of this valley, with its woods, its cultivated fields and its broad river, was upheaved. While upon the other side the plain subsided, and for a distance of a hundred leagues was transformed into a vast cavern of unknown depth. Upon that day the waters of the Jordan, suddenly arrested by the upheaval of the soil lower down the stream, must have flowed rapidly back towards their source, again to flow not less

impetuously along their accustomed incline, and to fall into the abyss created by the subsidence of the valley and the break up of the bed of the stream.

When, after the disaster, the inhabitants of neighbouring regions came to visit the scene of it, they found the whole aspect of the district altered. The valley of Siddim had ceased to exist, and an immense sheet of water covered the space which it once occupied. Beyond this vast reservoir, to the south, the Jordan, which formerly fertilised the country as far as the Red Sea, had also disappeared. The whole country was covered with lava, ashes and salt; all the cultivated fields, the hamlets and villages had been involved in the cataclysm.

In the eyes of a religious people, an event of this kind was necessarily regarded as a visitation sent by God, and thus the annals of Israel faithfully reflect the conviction of the people, when they represent it as a punishment for monstrous crimes committed by a population which had not even ten just men among it.

The record of this great catastrophe is preserved not only by Scripture, but by the living and spoken traditions of the East, all the legends of Syria, as well as ancient historians like Tacitus and Strabo, relating how Lake Asphaltite was formed during

the terrible shock and how opulent cities were swallowed up in the abyss or destroyed by fire from out of the earth.

But even if popular traditions had been forgotten, and if the writings of ancient authors had been lost, the very aspect of the country would suffice to show that it had suffered from some terrible subterranean convulsion. As it was upon the morrow of the catastrophe itself, so it has remained with its calcined rocks, its blocks of salt, its masses of black lava, its rough ravines, its sulphurous springs, its boiling waters, its bituminous marshes, its riven mountains, and its vast Lake Asphaltite, which is the Dead Sea.

This sea, the depth of which has never been sounded, evokes by its origin and its mysterious aspect, the dolorous image of death. Situated about 690 feet below the level of the ocean, in the depression of the soil caused by the earthquake, its waters extend over an area of a hundred square leagues to the foot of the salt mountains and basaltic rocks which encircle it. One can detect no trace of vegetation or animal life ; not a sound is heard upon its shores, impregnated with salt and bitumen ; the birds avoid flying over its dreary surface, from which emanate deadly effluvia, and nothing can exist in its bitter, salt, oily, and heavy waters. Not a breeze ever

stirs the surface of this silent sea, nothing moves therein, save the thick load of asphalte which now and again rises from the bottom to the surface and floats lazily on to the desolate strand.

The Jordan has remained what it was in ancient times; the blessed stream, the vivifying artery of Palestine. Taking their source in the spotless snows and pure springs of Mount Hermon, its waters have retained the azure blue of the sky and the clearness of crystal. Before the catastrophe, the Jordan, after having traversed and fertilised Palestine, found its way into the Gulf of Arabia, but now, as upon the morrow of the shock which broke up its bed, its waters are lost in the sombre abyss of the Dead Sea.

IV.

The coast of Puzoli.—The Temple of Serapis.

THE remains of an ancient temple of Jupiter Serapis are often instanced as an irrefutable proof that the coast upon which these ruins stand has been alternately raised or depressed. I am speaking of Puzoli, in the neighbourhood of Naples, where the coast is formed of regular strata of sand and volcanic stones containing remains of marine

shells. In 1749, the remains of a temple of Jupiter, an imposing building, the design of which was easily to be identified, were discovered there. This monument was 117 feet in length, and the grand inner courtyard was surrounded by small cells which were probably intended for the use of bathers. It may be that the whole building was not a temple, but a Roman bath. Three marble columns were still standing, but they were half buried beneath the soil, and when this was cleared away, it was found that they were about forty-two feet in height. These columns are cut out of a single block of marble, and for a height of about twelve feet they still retain their primitive polish, but below this is a space of about nine feet which is honey-combed with small and deep cavities, such as the shellfish called pholades have made in the neighbouring rocks.

The three columns lean slightly in the direction of the sea, and the pavement of the temple is generally covered with water. From all these facts the conclusion has been drawn that the temple, formerly constructed upon dry land, was subject to the subsidence of the coast which followed the last great eruption of the Puzuoli Solfatare in 1198, just as its present elevation is attributed to the sudden formation of the volcano of Monte Nuovo in 1538.

The fact of the temple having been in turn elevated, and having subsided, is, however, stoutly denied by some people. It may be, after all, that



Columns at the Temple of Serapis, near Puzuoli.

the pholades were in the blocks of marble before they were shaped into columns, for the builders would have disregarded this trifling drawback, little thinking of the perplexity into which they would plunge the *savants* of future generations.

Moreover, it is a matter for surprise that neither the pavement of the temple nor the three monoliths which have remained standing should have suffered at all from these shocks, however mild we may suppose them to have been.

V.

Measured undulations of the soil.—Pressure exercised upon the soil by the ocean and the atmosphere.—While one portion of the globe is slowly being raised, the other portion is gradually being lowered.—Character of this slow and universal undulation.

WE have seen that the traces of certain shell-fish discovered upon the columns of an ancient temple justify the conjecture, at all events, that the soil around this temple has first subsided, and then been elevated again. In the same way, the elevation of the coast-line may be followed by means of the submarine produce discovered upon the shelving edge of the beach, while the gradual subsidence of the coast may be traced by means of the terrestrial vegetation and even buildings found beneath the level of the sea. A proof of this subsidence is also to be found in the presence at a great depth of the vestiges of certain animals which can only live in salt water of not more than a certain depth. Thus, when we find coral trees

and forests of polypary upon the shores of the islets at a great depth in the Pacific Ocean, it is safe to assert that these polyparyies were formerly upon the surface of the water, and that at this spot the bed of the sea has subsided. It is safe to affirm this, because the polypes which constructed these trees of coral, and produced these silicious forests, now deserted, can only live near the surface. Charles Darwin, who examined with scrupulous attention the archipelago and the coral reefs of the Southern Seas, deduced from this fact the conclusion that in many places the bed of the ocean is gradually subsiding. Nor is it the earthquake shock alone which causes the soil to subside and to rise; the terrestrial surface is affected by continuous motions extremely slow but extremely powerful, though they do not impress the human mind as violent and sudden shocks do.

The waters of the ocean exercise upon the surface which they cover an enormous pressure, which varies not only with the depth of water, but with the motion of the waves and tides, a motion which is ever displacing the mass of water, and which, therefore, is constantly modifying the pressure of the column of water. The consequence is, that owing to the effect of this ever-varying pressure, the immense bed of the ocean is constantly vibrating at all parts, as if a vast

battering-ram were incessantly striking it. More changeable, perhaps still, is the action of the air and atmosphere. The sudden storms, the periodic undulations, the capricious whirlwinds which stir its depths, are ever acting, imperceptibly as it were, upon the surface of the soil ; and, while the external surface of the earth is thus vibrating beneath the shocks which it receives from the atmosphere and the water, the whole planet is being worked upon internally by the effluvia of heat, the floods of fire, the currents of electricity and magnetism which shake it to the centre.

From these imperceptible shocks, these slight vibrations, and these slow undulations, results in time a general movement, a periodic oscillation of the whole surface of the earth. In one place a continent gradually rises in level for a long series of centuries, and then subsides again ; in another the surface of the soil gradually sinks beneath the waters, only to be elevated again with equal slowness.

At the present moment a vast region, extending from the north of Asia, through Central Asia, Europe, and the basin of the Mediterranean to the African coast, is, as a whole, gradually rising. Italy, France, and the peninsula of Spain and Portugal, agitated by a long and insensible quiver of the soil, are gradually rising in a southerly di-

rection, while to the north of this zone the soil seems to be subsiding from year to year. Thus, in Flanders, regions formerly covered with dense woods, have become willow-beds ; while further north a large tract of country, formerly inhabited by a prosperous set of cultivators, is now covered with the waters of the Zuider-Zee, the bed of which continues gradually to subside.

The cliffs of Great Britain bear traces towards their summits of the indentations made by the shell-fish, the pebbles and the sand, this being a clear proof that at one time the top of these tall cliffs was only just on a level with the sea.

In Sweden and Norway the coast gradually rises in the form of an amphitheatre to the foot of the mountains, and while already at a height of more than six hundred feet above the level of the sea, it is slowly reaching the lofty summits. The surface of this raised soil is covered with shells and coral-bunches, which are the *débris* of animalculæ now living in the adjoining sea at a depth of nearly 2,000 feet, so that the coast has slowly risen 2,600 feet in the course of several centuries.

In the north of Russia, both in Europe and Asia, the surface of the land contains a great many shells absolutely the same as those of the Frozen Sea, and in the plains of Siberia may be seen a quantity of wreckage which was thrown upon the land by

the currents when this district was just under water. The natives call this wreckage "Noah's Wood," being under the impression that it is the remains of the ark.

Thanks to the patient researches of Darwin, and to the not less remarkable investigations of many other naturalists, it may be affirmed that the detached islands, and the groups of islands which extend from the archipelago of Hawaii across the Pacific, for a length of 9,000 and a breadth of 1,250 miles, are the remains of an ancient continent which has been submerged beneath the floods. This continent now forms the bed of the ocean, which itself is gradually subsiding. It is easy to follow this slow subsidence of the islands which rest upon this moving foundation, and many an archipelago, but lately verdant and full of people, has been seen gradually to subside, and finally to disappear in the waters of the ocean.

The western coast of South America, from Venezuela to the Straits of Magellan, is plainly rising, and even the snowy peaks of the Andes seem to be lifting their heads higher into the sky. Upon the other hand, all the eastern coast, as well as the boundless plains of the Argentine Confederation, which in former ages had gradually risen, now seem to be subsiding again towards the level of the Atlantic. Moreover, the bed of the Atlantic

itself seems for many centuries past to have been slowly subsiding, from the coasts of the New World to beyond the island of Madeira and the Canaries, which are, perhaps, the last vestiges of the famed island of Atlantis. Thus, we see that the soil is not inert and rigid; upon the contrary, it is animated by a slow though perpetual undulating motion. When we find the dry land thus oscillating and undulating around the oceans, we are tempted to say with Antonio Moro, the Italian naturalist, that it is the earth and not the sea which is changeable and unstable. The course of events upon the surface is as if streams or oceans of fire were slowly rolling within the planet their waves of liquefied rocks, and as if the foundations of continents and the bed of the ocean were rising and falling according to the undulations of these mysterious waves.

But is it, after all, a subterranean undulation of this kind which causes the rhythmic movement of the bed of the ocean and of the dry land? This is uncertain; and the most which can be said is, that the surface of the earth does undulate noiselessly, regularly, and powerfully, like the surface of a sea which, though not tempest-tossed, is moved by a heavy swell. The only difference is, that while the wave of the sea accomplishes its motion in a few moments, the wave of the earth

takes several centuries to complete its course. It undulates so slowly, its motion is so regular, uniform, and measured, that the soil subsides beneath the feet of successive generations before they are aware of it. The powerful undulation lowers mountains, raises up the bed of the sea, alters the outline of continents, changes the physiognomy of the earth, and goes on from century to century without affecting the labour of the spider as it spins its delicate web, or that of man, as he erects his not less fragile tent.

The surface of the land subsides and rises like an immense chest heaving in regular and lusty breathing. It may be that there is, in reality, a breath of life ; it may be that this ceaseless pulsation, the cadence of which resembles the rhythm of the arteries and the beating of the heart, is the normal pulsation of planet life, and that the earthquakes, with their quiverings, their shocks, and their violent upheavals, are the equivalents of an acute crisis or of a raging fever.



SEA-QUAKES AND DELUGES.

Vessels meeting shocks while at Sea.—The agitation of the sea.—
Waves raised up by the disturbance in the bed of the ocean.
—The great wave during the St. Thomas earthquake.—The
Russian frigate *Diana* in the Bay of Simoda.—Flooding of the
Peruvian coast.—Marine undulations caused by earthquakes.

It is easy to understand that the terrible earthquakes which shake continents and overthrow everything which stands upon the surface disturb not less deeply the depths of the ocean. Thus,

they agitate the floods, and produce what may be called the sea-quake.

Vessels passing in the vicinity of earthquakes often experience severe shocks. Thus it happened that, on the 21st of August, 1856, the French vessel *Tartare*, while off the coast of Algeria, between Stora and Djidjelli, suddenly received two such violent shocks that all of the crew rushed on deck, thinking the vessel had gone aground, or struck upon a reef. The sea was calm, and the vessel was in deep water, not near any reef or sandbank, but it was ascertained that there had been some sharp earthquake shocks in the neighbourhood of Phillipville, and that the centre of the disturbance must have been at the bed of the sea, off Djidjelli, not far from where the *Tartare* then was.

During the earthquake in the Japanese island of Nipon, in December, 1834, the waters in the bay of Simoda were in a state of great agitation, and formed such eddies that the Russian frigate *Diana*, at anchor in the port of Simoda, turned round forty-two times like a top, and the cables and chains of its anchor were at once snapped as if they were so many threads.

A great many instances might be given of these disturbances at sea, which have sometimes been so violent and sudden as to break off the masts, and cause the vessel to spring a leak.



"THE RUSSIAN FRIGATE *DIANA* TURNED ROUND LIKE A TOP."

In some cases the effect of the shock has been to raise up the immense body of water and hurl it upon the coast which was itself being moved by the earthquake. When this occurs, the quaking of the sea is always a phenomenon not less sinister than grandiose, more appalling perhaps and quite as disastrous as the quaking of the dry land. Whether the waters receive the shock from the adjoining shore, or whether it occurs at the bed of the sea itself, the waves, suddenly stirred up, rise mountains high and break upon the shore, carrying with them, as they recede, ships and their crews, towns and their inhabitants.

Upon the 18th of November, 1867, when the first shocks of earthquake had been felt in the island of St. Thomas (West Indies), the vessels in port began to swing about, the anchor chains snapped off, the masts were broken, and then arose an enormous wave, perhaps the greatest which the human eye ever beheld.

This terrible mountain of water had begun to gather about six or eight miles to sea, and to the south of the island of St. Thomas, between it and the island of St. Croix. One large wave, travelling in a northerly direction, struck the rocks and scattered islets near the island of St. Thomas. At this point, the wave was lashed into further fury by the simultaneous action of fresh shocks

which upheaved the bed of the ocean and raised another column of water, which, joining to that coming in from mid-ocean, formed a body of water more than ten miles in length. This mighty wave dashed itself, with a terrible roar, upon the island of St. Thomas. As it struck against the mountain which surrounds the port, the force of its impact was broken, but its waters, nevertheless, forced their way through the breach which forms the entrance to the port, and flooded the ruins of the city, which had just been razed to the ground by the subterranean shocks.

Just as the wave touched the shore, another and very violent trepidation of the soil occurred. This lifted up the waters as if by an invisible hand, and with the rapidity of lightning, they rushed out of the port, carrying with them in their abysmal depths the men-of-war and a great many merchant vessels. All this was the work of a few minutes only. The mighty wave continued to recede, and moving towards the south inundated the island of St. Croix, with a host of other islands and islets, notably the island of Saba, which disappeared entirely beneath the floods, steep as its coast-line was. Although the wave had already travelled more than 120 miles it was still a hundred feet high when it swept over this island. The marine undulation extended beyond the island of

St. Vincent, the terrible volcano of which had been called into activity after a sleep of half-a-century. Finally, the wave, after having travelled a distance of 500 miles, reached the island of Granada, two hours after the catastrophe of St. Thomas. As it struck the shores of Granada, a severe shock was felt upon the island, and a volcano burst forth, from the bottom of the sea, on the spot formerly occupied by a large village which had disappeared in the abyss after an earthquake which occurred in the early part of the eighteenth century. After having inundated a portion of the island of Granada, where it did great damage, the wave quietly receded and spent itself upon the shore. For a few moments the sea eddied furiously around the island above the submarine volcano, from which ascended into the air volumes of sulphurous vapour, and then all became calm and peaceful as before.

Upon the 23rd of December, 1854, when the earthquake occurred in the Bay of Simoda, Japan, the sailors on board the Russian frigate *Diana* noticed at ten in the morning, about a quarter-of-an-hour after the first shock, a big wave coming in from the sea towards the port. As the sea rose rapidly upon the shore, it seemed to the sailors on board as if the town was entirely submerged. This first wave was at once followed by a second,

and when these two waves had receded, at a quarter-past-ten, all that remained standing in the town of Simoda were the walls of an unfinished temple. Immense waves continued to roll in at intervals of ten minutes, until half-past-two in the afternoon. The frigate, after having turned round like a top, and after having gone aground five times, eventually sank. Part of the population was swallowed up by the sea ; all the shipping anchored in the bay was destroyed, and the wreckage of it was discovered two miles inland.

The terrible earthquake which ravaged the island of Jamaica upon the 7th of June, 1692, lashed to fury a considerable part of the Indian Ocean. Immense waves suddenly invaded the town of Port Royal, and in less than three minutes they submerged 2,500 houses, including even the highest, beneath 33 feet of water. The vessels were carried away from their moorings, and a large English frigate, the *Swan*, borne by the flood above the steeples of the town, was stranded upon the summit of a building and burst in the roof of it.

In February, 1783, when the severe shocks of earthquake in Calabria were overthrowing towns and villages upon the mainland, a heavy sea swept the well-known rock of Scylla, and after having at one swoop carried off two thousand persons as-

sembled on the shore, it forced its way into the port of Messina, sank all the ships there, destroyed the long line of marble palaces which faced the sea, and caused the death of more than twelve thousand persons.

All the coast of Peru was disturbed in 1746 by severe shocks of earthquake which destroyed Lima, and many other localities. At the same time, the sea rose and a mighty wave, more than 60 feet high, burst in upon the town of Callao, the most important sea-port of the country, and also the port of Lima the capital, situated further inland. The floods swallowed up all the town of Callao, and carried away the very ground upon which it was built; so that the present town has not, as is generally supposed, been rebuilt upon the site of the former one, but at some considerable distance. The vessels were driven on shore, carried to the distance of three miles or more, broken up and shivered, and their crews all drowned. It is said that only fifteen out of the whole population succeeded in reaching Lima. These immense waves travel with great rapidity almost incredible distances. Thus, during the Lisbon earthquake of 1755, the wave, sixty feet high, which came in upon the town from the mouth of the Tagus, receded as quickly as it had come, and travelled back over the Atlantic Ocean, the depths of which

were as much disturbed as the soil of the continent. This mighty wave overleaped the ramparts of Cadiz, and after having broken in fury upon the coasts of Great Britain and the island of Madeira, it travelled on to the shores of the New World and to the island of Martinique. Thus the marine wave, raised up at the mouth of the Tagus by an inland shock, travelled no less than four thousand miles.

The great wave produced by the earthquake of December, 1854, in Japan, spread from the bay of Simoda across the Pacific Ocean ; and, travelling at the rate of seven-and-a-half miles a minute, broke upon the shores of California, after having travelled five thousand miles in twelve hours.

In 1868, and 1877, there were several sharp shocks of earthquake upon the coast of Peru, and they were accompanied by violent disturbances of the sea. The shock of May 9th, 1877, ruined the town of Iquique in Peru. Waves seventy feet high burst upon the shore, and the undulation travelled rapidly across the Pacific, reaching Japan the next day, and creating great disturbance all along the coast, from Hakodadi to Sagami. The marine wave had travelled the enormous distance of 8,760 miles, between Peru and Japan, in twenty-three hours, its mean speed having, therefore, been 654 feet per second.

The terrible wave produced by the subterranean commotion which destroyed the Sound Strait in August (26-28), 1883, after having inundated the coasts of Java and Sumatra, submerging whole islands and making thousands of victims, pursued its impetuous course across the Indian Ocean, in the shape of an immense bore-wave. This wave reached the coasts of the Mauritius, and the island of Réunion, 3,500 miles from the Sound; and then, sweeping round the continent of Africa, it touched the French coast, the wave-register at Rochefort having marked, on the 28th of August, a very great height. This rise was doubtless caused by the wave which, starting from the Indian Ocean, expired upon the coast of France.

11.

Deluges and Earthquakes in Greece and China.—Atlantis swallowed up in the Ocean.—The Universal Deluge.

MARINE inundations of greater proportions than this one have in times past produced terrible catastrophes, the recollection of which has been handed down from age to age. In a night of the year 373 B.C. there was a violent earthquake throughout Greece, and when the sun arose upon

the Peloponnesus, the two well-known towns of Bura and Helice had completely disappeared. The latter, although several miles inland of the Gulf of Corinth, had been engulfed in its waters, and long afterwards, when the waters of the gulf were calm, a mysterious and desolate city might be descried in their depths. This was the once superb Helice, with its houses in ruins and its temples and marble columns broken to pieces.

The tradition of terrible inundations following upon earthquakes had long been handed down among the Greeks, and in the nineteenth century before Christ the whole population of Attica was drowned by the inundation which followed an earthquake. This was called by the Greeks the deluge of Ogyges, after the king who then reigned in Attica.

At the same period, according to some authors, three centuries later according to others, an earthquake in Thessaly was followed by the overflow of rivers and the inroad of the sea; and this catastrophe, called after King Deucalion, annihilated the population, the king and his wife Pyrrha, according to tradition, alone escaping upon a vessel, which, at the end of a week, grounded upon Mount Parnassus.

The tradition of these two disasters was con-

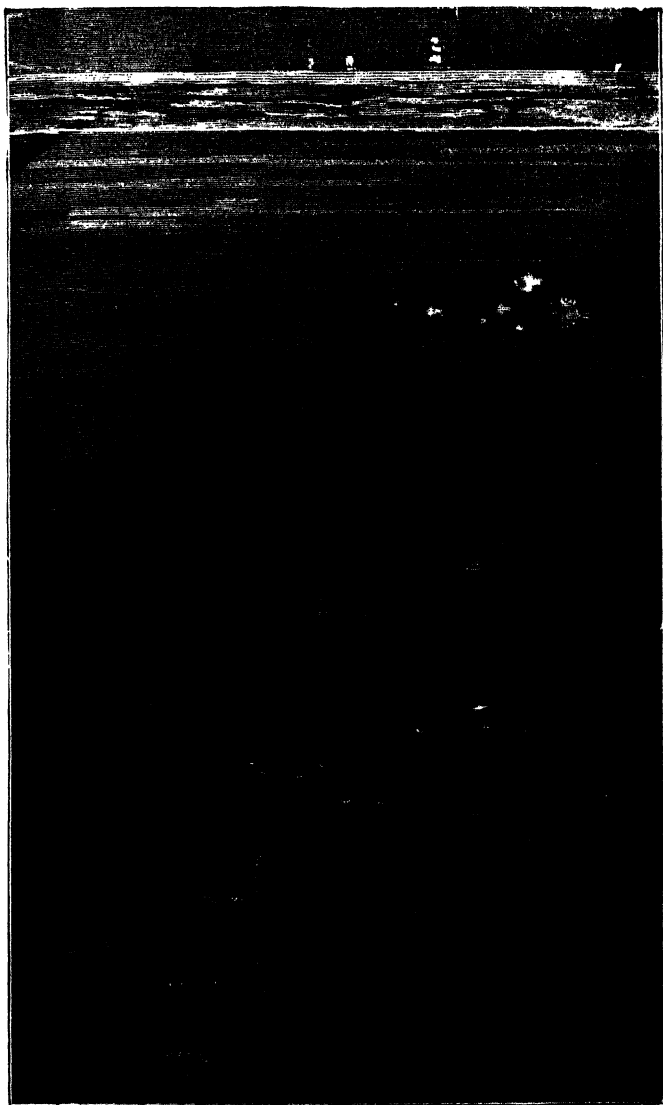
nected with that of a still more ancient catastrophe, and one far more extensive in its effects, as in about the year 2400 B.C., a terrible earthquake made itself felt over a vast tract of country, including the Chersonesus with Tauris, all the bed of the Black Sea, Thrace, Greece, Asia Minor, the Mediterranean, and perhaps even the bed of the Atlantic. At this period an isthmus separated the Black Sea from the Sea of Marmora, but the shock broke up the land, and formed the Strait of Cyanes, or, as it is now called, the Strait of the Bosphorus. The two seas met in fury and covered the whole of Greece with their waters, the deluge being such that all the inhabitants of Greece and Asia Minor, with the exception, perhaps, of a few shepherds upon the highest mountains, perished. The recollection of this catastrophe lived longest in the islands of Samothrace and Rhodes, in Phrygia and among the Egyptians, though the latter seem to have suffered very little.

It is probable that the same shock also affected the high table-lands of Central Asia, for almost at the same moment there occurred the deluge of Yao, which is handed down by Chinese tradition and in many curious monuments. Violent earthquake shocks broke up the eastern shore of the sea which now occupies the vast territory known as the desert of Mongolia, and the waters of this

immense reservoir, being directed upon the North of China, drowned the whole population.

It may well be that it was as a consequence of a like earthquake that the famed island of Atlantis, whose tragic story has been handed down to us by Plato, was engulfed in the floods.

According to an ancient tradition, transmitted by Egyptian priests to Solon and adapted by Plato, there was formerly in the Atlantic Ocean, beyond the pillars of Hercules, an island greater than Africa or Asia. This island was Atlantis, which in size was more a continent than an island, and gave its name to the ocean by which it was surrounded, being placed between Europe and another continent then unknown. The island of Atlantis had become the home of a great and mighty nation, the civilization of which was equal to that of the Greeks and the Egyptians. The kings of Atlantis had dominion westward over all the islands adjoining, and over the shores of the mysterious continent, while eastward their sway extended, from island to island, as far as the coast of Africa, and, beyond the Straits of Gibraltar, threatened the supremacy of the Mediterranean. The men of Atlantis, in one supreme effort, attacked Greece, Egypt, and other nations; whereupon the Athenians placed themselves at the head of a coalition to repel the



LAND ENGULFED BY THE WATERS OF THE OCEAN DURING AN EARTHQUAKE.

invader. Deserted by her allies, Athens had to rely upon her own forces, and, by virtue of her heroism, saved the people of Europe from subjugation. When the struggle was about to recommence, an earthquake swallowed up in one night all the Greeks capable of bearing arms, while at the same time the island of Atlantis was engulfed in the depths of the ocean.

There is some reason for thinking that these deluges in Europe and Asia, together with the sudden swallowing-up of Atlantis, may have been the accompaniment of the catastrophe which is recorded in the Book of Genesis. According to certain historians, the deluge occurred about 3500 B.C., while others place it a thousand years later, this being about the date of the catastrophes which occurred in China, Europe, and the Atlantic ocean. It is probable, therefore, that the Bible and ancient tradition relate the same event, and it was not only the oldest but the greatest earthquake upon record, for it extended at least from the western side of the Atlantic, over Europe, Africa, and Asia, to the shores of the Great Ocean, which, according to Indian tradition, then covered the land with its waters.

Since then, there has been no similar catastrophe, but the phenomena which in our day accompany earthquakes enable us to understand

how this awful catastrophe happened after several violent shocks : the elevated plains of Asia, with their chains of mountains, rivers, large lakes, and inland seas, would have been suddenly upheaved, just as recently in America and India, vast territories have suddenly been lifted to a higher level by underground shocks. The raising up of this lofty region of Asia, disturbed the water-shed system ; rivers overflowed, and seas and lakes poured their waters upon the plain. Nearer to the shore, isthmuses were torn asunder, and while their rupture brought about the union of seas heretofore divided, the vast oceans, the beds of which vibrated and trembled, hurled their gigantic waves over whole continents which they flooded, and over islands which were engulfed for ever in their abysses. It was a terrible catastrophe, involving an universal deluge. The evaporation of the boundless sheet of water saturated the atmosphere, and formed dense clouds in the sky, whence the water fell again in torrents upon the inundated earth. As we read in Genesis vii. 11, 12 : " The same day were all the fountains of the great deep broken up, and the windows of heaven were opened. And the rain was upon the earth forty days and forty nights."

In this immense cataclysm, the beds of rivers, the waves of the sea, and the rain from heaven

were mingled together, covering the plains, filling the valleys, roaring around the mountains, hollowing out the slopes of the great volcanoes of Asia, surging up to the summits of these enormous mountains, swallowing pasturages and flocks, forests and wild beasts, fields and crops, towns and hamlets with their myriads of inhabitants.

Ever since these ancient days, the underground forces of nature have not ceased to agitate land and sea, and although the shocks of earth and sea have not been quite so vast, they still remain mysterious phenomena, endowed with irresistible power.

EARTHQUAKES IN THE ISLAND OF ST. THOMAS.

I.

The Virgin Islands.—St. Thomas, the most beautiful island of the group.—Often visited by cyclones and earthquakes.—Cyclone and earthquake in 1837.

PASSING the island of St. Martin, in the Indian Ocean, the traveller, bound westward, soon reaches a labyrinth of islands and islets between which the sea winds with supple grace, forming a devious canal along which he sails placidly as upon a river winding through some vast park. Christopher Columbus named this group of islands, “the Virgins of St. Ursula,” and they are the pearl of the Indian Ocean, as, covered with odorous plants and crowned with masses of verdure, they rise from the waters like a group of sisters and embalm the air with their perfume.

The most beautiful of the group, is the island of St. Thomas, the delicate outline of which may be descried from a distance upon the horizon. The view of it is beautiful, especially when one enters the port at sunrise, with the town rising like an amphitheatre upon the slope of the hill, and

extending over the richly clad valley at the other end of it. The mountain, which girdles the whole island, very lofty in the northern part, descends towards the centre in gentle undulations, forming gorges which are full of flowers and bright insects, ravines rich with sulphur springs, and clad with magnificent trees. To the west and the east, the slopes of the mountain are steeper, and to the south it opens out and forms a hollow for the ocean. The waters of the ocean enter between two lofty hills, and extending to the foot of the hills upon which the town is built, form a wide oval bay of extreme beauty.

Thanks to this natural port, in which the largest vessels can ride in safety, the town of St. Thomas has become an important commercial centre.

Like everything brilliant and prosperous in this world, the little island of St. Thomas seems condemned by nature to perpetual vicissitudes. It has gone through strange reverses and catastrophes. It was at one time in the hands of corsairs and filibusters, and there is still to be seen upon a lofty hill a tower, now covered with creepers and flowers, which was once used as an observatory by brigands. It stands near the house where those well-known French naturalists, Henri and Charles Sainte-Claire Deville, whose researches upon earthquakes are so highly es-

teemed, were both born. When the pirates were driven out of the island, and its port had become a favourite refuge of war-vessels and merchantmen from Europe, the Maritime Powers disputed possession of the island, which eventually remained in the possession of Denmark.

The town itself was several times bombarded and sacked, while the whole island was ravaged and laid waste by earthquakes and hurricanes. But, thanks to the fascination which it exercises and to the energy of its inhabitants, it has always been able to flourish anew.

In 1837, it was visited upon the same day by the double scourge of an earthquake and a hurricane. It was upon the 2nd of August, and although half a century has elapsed, I can remember the incidents of the drama as well as if it had only happened yesterday.

The wind, which had been blowing a gale since noon, suddenly dropped about three o'clock, and there was a complete calm over the water, the air, and the earth. During this period of warning and terror-inspiring calm, my father and eldest brother galloped home in hot haste, and had the doors and windows of the house propped up with planks and rope. The house was a large one, and was built of wood upon a groundwork of masonry, which was itself founded upon the rock.

It would be difficult to imagine anything at once more supple and yet solid. Situated at a height of about 380 feet up on the slope of a hill, the house commanded a very wide view, at our feet being the town, while further on were the quays with their warehouses, and the port which, at the time I speak of, was crowded with shipping.

The doors and windows were scarcely closed, when a most terrible noise was heard. It was the hurricane which was coming upon us. It arrived in fury, howling and rolling black clouds before it, raising up the flood, and covering island and sea with black darkness. When the first shock struck the house, the latter shook and bent, but was not carried away. For six hours the hurricane raged with ever-increasing violence. Débris of all kinds were turned about in the air, tiles and slates were rained upon our roof, and driven into the beams and rafters; trees, torn up by the hurricane and carried along branches and all, scudded by the walls or fell violently upon the terrace; lightning lit up the sky, and the rolling of thunder mingled with the roar of the tempest.

At about ten in the evening the gusts of wind became less frequent, the thunder ceased, and the end of the storm seemed at hand, when a sudden underground noise was heard. All round

the house, and along the bed of rock upon which it stood, there was a crackling, splitting sound, immediately followed by severe shocks. A confused noise of voices and lugubrious groans were heard from outside. My father threw open a window. The whole island seemed to be in a tremble. At this moment a fresh shock agitated it still more deeply, and then a bright flame shot up to the sky. It emerged from the ruins of a house which had just fallen in, and in a moment the whole town was on fire. I seem still to have in my ears the cry of anguish wrung from my father ; I seem still to see the despair and terror of my mother, as she rushed to the door, dragging me with her.

The inflammable matter, driven by the wind, which was again blowing a hurricane, lodged upon the roof, part of which had been carried away. It behoved us to fly, and to traverse the storm of fire. We had scarcely quitted the house when the high wall which encircled the property fell in. The burning cinders and the bitter foam of the ocean, which the hurricane of wind drove before it, flew in our faces, and the constant shocks caused the ground to undulate and give way beneath our feet. But we kept on our way without halting, the fire lighted at our feet serving to guide our footsteps. We scaled a mountain,



FAMILY TAKING FLIGHT UP A MOUNTAIN DURING A HURRICANE
AND EARTHQUAKE.

the summit of which was crowned with a very solid building, where we found a secure refuge, and when my father had seen us into a safe place, he went down into the town, whither his duties called him.

When day broke, the glorious and radiant sunshine of the West Indies lighted up, with its brilliant rays, the darksome work of the previous night. The whole country round was strewn with large trees, uprooted or snapped off, and all the plantations were destroyed. In the town the fire was dying out, and it was only here and there that the ruins were still smoking. The hurricane had swept away nearly all the wooden houses, those which had been lightly placed upon beams just above the soil being carried off as they stood, while the larger ones which had resisted the hurricane were overturned in an instant by the earthquake. The whole town, in fact, was filled with ruins, which told of the violence of the catastrophe. The port, so gay and animated the day before, was dreary and deserted, a few masts here and there emerging from the water ; while all along the shore, and even upon the slope of the hills were scattered wreckage and corpses of sailors. When in the morning my father took us back to our ruined home, he was overcome with fatigue. The double catastrophe had

annihilated his fortune, but he was self-possessed, while his countenance betokened an inward serenity, due, no doubt, to the knowledge that he had been prodigal of consolation to some and of succour to others, who, but for him, would have been crushed beneath the ruins.

II.

Cyclone of Oct. 29, 1867.—Energy of the inhabitants.—Earthquake of Nov. 18, 1867.—Weather very calm at the time.—Underground mutterings.—Violence of the shocks.—Collapse of the town.—An enormous wave rises up in mid sea.—Terror of the inhabitants.—The wave invades the ruins of the town.

THIRTY years had elapsed and the memories of the catastrophe of 1837 had gradually faded away, when, upon the 29th of October, 1867, at noon, a terrible cyclone broke over the island. For eleven hours it raged impetuously, blowing in contorted eddies from all parts of the horizon, so that the mischief commenced by one blast of the hurricane was completed by a second. Less violent, perhaps, than that of 1837, this hurricane nevertheless did great damage; for the town, having increased in size, had many buildings of greater importance, while there was much more shipping in the port. The cyclone of 1867 drove fifteen large steamers and many other vessels on

to the shore, while, in the midst of the hurricane, several slight shocks of earthquake were felt. The inhabitants set to work with their accustomed energy to repair and to rebuild what the cyclone had damaged or destroyed, and the harbour was soon re-peopled with merchant shipping, carrying the flags of different nations, and with men-of-war, which, on their departure, as on their arrival, thundered their greeting to the town.

All this served to obliterate the sense of the disaster, when, upon the 18th of November, three weeks after it had occurred, the island was shaken to its foundations by the most violent shock of earthquake which it had ever experienced.

About three in the afternoon, just at the hour when business is at its height, and when traders from the neighbouring islands of Guadaloupe, St. Martin, Porto Rico, St. Domingo, Cuba, Jamaica, &c., were fully occupied, a long and piercing groan and sob seemed to issue from the bosom of the earth. The whole island shook, and fear entered into men's souls. When the subterranean voice had ceased to groan, there was a mournful silence, amid which animals were seen huddling together and birds gathering upon the trees with plaintive cries. Then followed an underground buz, like that of a gigantic swarm of bees, and after that the earth quaked most violently.

The whole population rushed out of the houses, the inhabitants in most cases making for the quays, the hills, and the open country ; but during their flight, many aged persons and children were crushed by falling walls. The soil undulated and trembled as if it were some liquid mass, and it was easy to feel beneath one's feet the motion of the subterranean waves travelling from south to north. At first, the shocks were so numerous and followed one another so quickly, that it was impossible to note the interval which separated them. After that there was a long pause and everyone thought that the earthquake was over, when three further shocks moved the island to its very foundations.

From the points where people had taken refuge, a sinister sound was heard, and suddenly a cloud was seen to rise like a funeral pall above the town. This was caused by the falling in of the houses, warehouses and massive buildings of granite which had resisted the first shocks. A great cry went up from the population, which, kneeling upon the shore to implore the Divine mercy, witnessed the dread spectacle in blank despair. But the thought that the aged and the infirm had in many cases been left behind, imparted fresh courage to those who were able to render active help ; and they were starting off to

see what could be done, when a phenomenon of unspeakable grandeur held them spell-bound with awe.

Beyond the port, and clear out at sea, appeared a body of dazzling whiteness, very voluminous



Immense ocean wave lashed up by earthquake shocks.

and increasing in size. At first, it was taken for a mountain arising out of the depths of the sea, but the enormous mass undulated, and seemed to draw nearer to the shore. It was a wave of prodigious height, and at least seven miles wide, for it overlapped the two extremities of

the island. Like the subterranean earth-wave, the water-wave was travelling in a northerly direction. Massive and heavy, it advanced slowly and with so regular a motion that one could not detect the slightest break or asperity in the surface of its waters. With a deep roar and a crest of foam, it rolled towards the shore, those who were gathered there flying towards the hills ; but their progress was impeded and imperilled by the falling of walls and dwelling-houses. The mighty wave broke against the mountain which protects the port. Floods of foam, clouds of spray and torrents of vapour eddied along the slope of the mountain, and just at this time a dark cloud streaked with flashes of lightning was seen hovering over the sea.

Although its force was broken by the shock, the wave cleared the summit of the mountain, and fell like an avalanche upon the opposite slope. Crushing all that came in its course, carrying away ships and covering with its hoarse roar the despairing shriek of the sailors, it invaded the port and covered the ruined city with a white shroud of foam. It receded as suddenly as it had come, carrying off the whole of its prey into the abyss, and for a few moments the port was quite dry ; after which the water returned peacefully to its accustomed level.



'CARRYING AWAY SHIPS, AND COVERING WITH ITS HOARSE ROAR THE
DESPAIRING SHRIEKS OF THE SAILORS.'

[p. 106.]

When a first glance could be taken at the extent of the disaster, a mournful spectacle met the gaze. The town was in ruins, and the waters had mingled these ruins into one confused mass. Rocks and débris of various kinds covered the ground where once stood the beautiful village of Gregories, like a nest of verdure and flowers upon the shore, just by the entrance to the town. The two large batteries which protected the entrance to the port had been swept away, with their guns and artillerymen, and broken boats were stranded on the rocks, while from afar sailors held out signals of distress from vessels which had in some miraculous manner escaped destruction, among them being a fine frigate of the United States navy which came to the relief of the shipwrecked. Most of the vessels, however, had been swallowed up and had left no trace behind them.

The underground disturbance did not cease all in a moment, as now and again the terrestrial waves were distinctly felt beneath one's feet, and they served to keep up a feeling of terror among the people, who remained encamped beneath tents for some days. This feeling of emotion is invariable among people who have experienced a severe earthquake. It is due not to the recollection of the distressing scenes which have been witnessed, so much as to the sudden collapse of the complete

confidence hitherto felt in the immovable steadiness of the ground. From our earliest childhood, we have been accustomed to regard the earth which our implements labour and upon which we build our fleeting home, as motionless and silent, while everything upon its surface moves and palpitates and passes away. And all of a sudden we hear it moan and roar; we see it undulate and tremble! From this hour, we scarcely dare trust the ground we tread, and for some time we shudder at the slightest sound heard in Nature. For the population of St. Thomas these first few days were days of mourning, devoted entirely to the dead who were taken from out of the ruins and buried amid universal grief. But in the West Indies, Nature is full of caresses, and under the influence of a blue sky, hope soon finds its way into the heart, while the same radiant sunshine which dispels the abundant dew also dries the bitter tears of suffering humanity. Gradually, men's courage revived, and they trusted themselves once more to the town, while, thanks to the proverbial generosity of the West Indian populations, relief was soon provided for the indigent. The wealthy merchants of the island had placed their fortunes at the disposal of the committee of relief, and foreign vessels soon reached the port, bringing with them gifts in money and in kind from all the

islands of the archipelago, and from Florida, Central America and New Granada.

The vessels which came from the islands situated to the south brought word that the terrible shock had been felt in all these islands, but to nothing like the same extent. The island of St. Croix, which is the nearest one to the south of St. Thomas, had suffered a good deal; about 500 miles further, a submarine volcano had emerged upon the coast of the island of Granada, and a sudden rise of the tide had spread consternation among the inhabitants. It also appeared that upon the same day the volcano in the island of St. Vincent, which had been quiet for a long time, had shown signs of renewed activity. When this volcano is seen during one of its long periods of repose, it is difficult to believe that this mountain, scarcely higher than Vesuvius and of such a peaceful aspect, is the formidable monster whose wrath causes land and sea to tremble, from the mountains of Venezuela to the Gulf of Mexico. Its return to life is always sudden and terrible. In 1811, when it awoke from a sleep which had lasted more than a century, torrents of fire poured forth from its immense mouth, and in its sudden fury it roared so loudly that its voice was heard 750 miles away in the precipitous valley of Caracas, in the plains of Calabozo, and as far as the

shores of the Apure, one of the affluents of the Orinoco. And while the earth shook upon the lofty plateau of Venezuela, where the wealthy city of Caracas was laid in ruin, the ground around the volcano in the island of St. Vincent scarcely vibrated. This strange phenomenon again occurred in 1867, for while the island of St. Thomas, 400 miles away, was violently shaken and the waters of the ocean were driven in fury over the island, the region immediately around the volcano remained unmoved.

Six weeks after the catastrophe, a small despatch boat, the *Sphinx*, flying the flag of Admiral Sir Rodney Mundy, commanding the English squadron for North America and the West Indies, came into port. In order to form a correct idea of the extent of the disaster, the admiral, after having visited the town, returned on board, and in the company of the English consul slowly sailed round the port. He was not slow to express his sense of surprise at the magnitude and extent of the disaster, and at the energy of the inhabitants in repairing the damage. Sir Rodney Mundy had left his squadron in the bay of the island of Tortola, and had embarked upon this small despatch boat because he had been told that the harbour of St. Thomas was now inaccessible to large vessels, but to his astonishment he found more than a

hundred ships at anchor there. The *Sphynx* left the same day, but Sir Rodney Mundy returned twenty-four hours later with his whole squadron, and the *Royal Alfred*, which was his flag-ship, fired a salute to the nascent city.

Nineteen years have passed away, and all traces of the catastrophe have disappeared. The town has recovered her prosperity, and the whole of the little island has assumed again the splendour of its native beauty. Long may Providence preserve it to her.

VOLCANO FIRES AND EARTH- QUAKES.

I.

Volcanic eruptions followed by violent shocks.—Earthquake in the island of Java, and eruption of the Maunaloa volcano.—Shocks and volcanic eruptions in the islands of the Indian Ocean.

THERE is a great diversity of opinion as to whether there is a close connection between volcanic phenomena and earthquakes: in other words, whether the subterraneous fire which gives birth to volcanoes, also produces the great earthquakes which agitate whole regions. Upon the one hand, many instances might be given of earthquakes which are evidently due to the action of the subterraneous fires, as of others not attended by any volcanic phenomenon. There is no means, therefore, of giving any direct answer, and the only satisfactory course is to collect and to compare certain important facts which enable one to see how closely the two phenomena are at times allied to each other, and how hard it is at others to establish any connection between them.

Take, for instance, the island of Hawaii, in

which earthquakes are so frequent. Three volcanoes are to be seen in this island : Maunakea, Hualalai, and Maunaloa, with its two vast craters, one upon the summit, and the other upon the flank of the mountain. The former is the



Distant Volcanoes causing earthquake shocks.

crater of Moku - a - veo - veo, the latter that of Kilauea, the greatest and the most active crater in the world. Yet never in the memory of man had the earthquakes which are so frequent in this island been simultaneous with volcanic disturbance, when in April, 1868, after several severe oscillations of the ground, the Maunaloa suddenly

began to roar, and, opening out its flanks, discharged streams of fiery lava. At the same instant the whole island rocked, and the worst earthquake ever experienced occurred during the fury of the volcano. These shocks lasted nearly a year, and they were so numerous that, as we have said, more than 2000 occurred in a month. It is clear that in this case the violent crises of the Maunaloa and the underground disturbance formed, as it were, one and the same phenomenon. Upon the other hand, it is difficult to give a valid reply to the argument which finds in the fire of these craters the cause of the violent shocks which the island of Hawaii experiences even while its volcanoes are dormant. At times, the disturbances which accompany the volcanic eruption are limited to a very narrow compass ; the summit of the volcano trembles without the least shock being felt in the lower parts of the burning cone, while at other times the whole mountain of fire vibrates and quivers without the commotion extending to the surrounding surface. Sometimes, again, the eruption of a volcano is followed by violent earthquakes all around. Thus, in the islands of the Indian Ocean, great volcanic eruptions are always accompanied by violent earthquakes, which sometimes do more mischief than the lava from the volcanoes. So it was in 1883, when the island of

Krakatoa, with its burning crater, was swallowed up by the waters, and the volcanoes of Java were all astir.

II.

The craters in ebullition regarded as safety-valves.—The Pasto volcano and the Riobamba earthquake.—The German traveller Reiss at Pasto.

IN the countries which are alternately ravaged by volcanic lava and subterranean commotions, the mouth of the volcano is generally regarded as a safety-valve, it being generally believed that the great shocks of earthquake occur while the volcanoes are at rest. It is even said that the crisis of the volcano calms down and dies out just as the earthquakes begin. In this connexion, it is said that, at the time of the Lisbon earthquake, Vesuvius, which had been belching forth volumes of vapour, ceased to do so, and that the floods of lava pouring forth from its side suddenly stopped. It is said, too, that the Stromboli, so impetuous and unceasing in its activity, was for a moment quiet in February, 1783, at the time of the Calabrian earthquake.

Some violent shocks which had been occurring throughout Syria, in the Cyclades and Eubœa, suddenly ceased just as a torrent of fiery matter

was bubbling up on the plains of Chalcis. Strabo, the great geographer, in relating this fact, adds :—
“ Since the mouths of Etna have been open and are vomiting fire, since masses of water and liquid lava can be forced out, the coast has suffered less from earthquakes than it did at the period previous to the division of Sicily from Italy, when all means of issue were closed.”

After the terrible shock of February 4, 1797, which destroyed Riobamba, the earth shook for eight months in South America and the West Indies, but upon the 27th of September, the sulphur mountain in the island of Guadaloupe, which had hitherto been regarded as an extinct volcano, had a violent eruption, and from that date the earthquake shocks ceased throughout the West Indies. When, towards the end of the year, the eruption of the volcano subsided, the earthquake shocks recommenced with extreme violence, and upon the 14th of December the town of Cumana, in Venezuela, was completely destroyed.

A thick column of smoke had been issuing since November, 1796, from the volcano of Pasto, called in the neighbourhood the *Galera* (the galley), from the shape of the cloud of ashes which sometimes floats above its summit. The mouths of the volcano are lateral and are upon its western slope ; but for three months the column of smoke rose so

high above the crest of the mountain that it was visible the whole time to the inhabitants of the town of Pasto. These inhabitants assured Humboldt that upon the 4th of February, 1797, they suddenly saw the smoke disappear without feeling the least shock. It was at the very moment when the town of Riobamba, 235 miles to the south, between the Chimborazo, the Tunguragua and the Altar, was being destroyed by an earthquake which Alexander von Humboldt describes as the most fatal recorded in the history of these countries so exposed to catastrophes of the kind. After this coincidence of phenomena, says Humboldt, how can we doubt that the vapours issuing from the small mouths, or *ventanillas*, of Mount Pasto had their influence upon the pressure of the elastic fluids which broke up the soil in the Ecuador and destroyed in the twinkling of an eye 100,000 souls?

After a long period of repose, the volcano of Galera was very much disturbed towards the end of 1872, when Herr Reiss, the German explorer, arrived in the country for the purpose of visiting the volcano, whose brusque variations were a source of much anxiety to the inhabitants of Pasto, situated at the foot of the mountains.

A few days before, Herr Reiss had achieved the unparalleled feat of reaching the summit of the

Cotopaxi, and looking down into the terrible crater of the mountain; and the news of his exploit was soon spread abroad throughout Ecuador and New Granada. The population of Pasto awaited his return with anxiety, feeling assured that so great a *savant* would not only be able to quiet the anger of the volcano, but perhaps to prevent the earthquakes from following upon the subsidence of the eruptions. He received a regular ovation, the authorities presenting themselves in a body to receive him, as well as the staff of the university, for Pasto prides itself upon being an enlightened city. The bishop and his clergy also came to congratulate him, and the crowd collected beneath his windows, anxious to see what measures this learned man would take against the *Galera* volcano.

III.

A mutual law seems to exist between volcanic eruptions and earthquakes.

M. ALEXIS PERREY, the well-known professor at Dijon, as well as Professors Emil Klugg of Chemnitz, Mérian and Otto Volger of Zurich, have established by ingenious deductions the fact that earthquakes are most frequent in winter,

while most volcanic eruptions take place in summer. At first sight, this fact would seem to prove that the two phenomena have not for the most part any connexion with each other, but a moment's reflection will show that this confirms rather than controverts the popular belief which sees in volcanoes escapes for subterranean fire and safety-valves, as it were, against earthquakes. From the fact pointed out by the professors just named, it results, not as M. Volger believes that volcanoes and earthquakes are phenomena independent of each other, but that they are, on the contrary, connected by a sympathetic bond, or, it should rather be said, have a common origin. We have here, in fact, the indication of a certain law of rhythm or harmony in the production of these two great and terrible phenomena. But, at the same time, if such a law exists, it is not absolute, as the eruption of volcanoes and the earthquake often occur simultaneously, a case in point having been already pointed out in connection with the catastrophe in the islands of Java and Sumatra in 1883.

IV.

Earthquakes in South America.—Are they due to the filling up of underground caverns?—Close connection between earthquakes and volcano fires.

MANY men of science have thought that the number of earthquakes due to the action of caloric or subterraneous fire, was limited to those which occur in the immediate neighbourhood of volcanoes. This is, in my opinion, a mistake, for among the violent earthquakes which occur at a great distance from them, there are some which evidently arise from the same causes as those which produce volcanic phenomena. When, for instance, a crater takes fire or a submarine volcano boils up at the very time when an earthquake is taking place 250 miles away, it is impossible not to regard the two phenomena as connected with each other, when similar occurrences are frequent in the same region.

In Central America, Venezuela, Colombia, Ecuador, Peru and Chili, the ground trembles the most at the foot of volcanoes; but it also trembles very violently at a considerable distance away from them. However, these distant shocks are in themselves, as it were, proofs of the subterraneous force which also produces volcanoes, emanating as

they do from the internal heat of the globe. In short, when one studies earthquakes in South America, divested of all prejudice and only anxious to arrive at the truth, it is difficult to avoid the conclusion that they have connection with the volcanic fires which are ever and again bursting forth from the slopes of the Andes, or illuminating its crests. When there has been an earthquake in Ecuador, it may be taken for granted that, not only will other shocks occur over all the immense territory commanded by the Andes, but also that a crisis is at hand within one or more of the majestic volcanoes which stand like a line of giants over the coast from the southern extremity of Chili to the furthest frontier of Nicaragua. And seeing how close is the connection between all these great phenomena, how can one doubt that they have in this region of the earth, nearly always, if not always, the common origin which Humboldt credited them with. This view seems to me to harmonize better with the facts than that of Darwin, Boussingault, Volger and my friend Elisée Reclus, who hold that the great earthquakes in equinoxial countries are due to the falling in of subterraneous caverns. Is it not reasonable and on that very account scientific, as there is absolutely no obstacle in the way, to attribute these shocks to the subterranean heat of

which the action and effects are visible all around, whereas there is no visible sign of any subterranean caverns falling in ?

But, it may be said, this is all very well when the two phenomena occur at about the same time, though at some distance apart, but how can it be so when a severe earthquake occurs in a volcanic region quite close to burning craters, and the volcano is not affected ? There is, for instance, the long chain of the Andes, with its terrible craters. At times, sudden and violent shocks occur there in a straight line, and disturb countries bristling with volcanoes in full activity, and yet do not have any visible influence upon them. Can it be said that these earthquakes are due, if not directly to the fire of these craters which remain quiet, at all events to the subterranean heat which keeps up the fire of the volcanoes in question ?

My simple reply to this question would be that the hypothesis which would attribute these earthquakes to the action of the subterranean fire, that is to say, to the volcanoes of the countries disturbed, would be neither less justifiable nor less scientific than that which would explain them by the falling-in of imaginary caverns.

When severe volcanic eruptions occur in Central America, it often, if not always, happens that there are also earthquakes in South America.

Thus, soon after the great eruption of the volcano of Coseguina, the whole of New Granada was shaken by convulsions of the earth, and the subterraneous thunder was heard simultaneously in Nicaragua, in the towns of Popayan, Bogota, Santa Marta and Caracas, and in the islands of Hayti, Curaçoa and Jamaica. Whenever there have been violent shocks in Venezuela or Chili, the Republic of Costa Rica has suffered, and it has invariably been the towns of San José, Heredia, and Barba, which are close to the volcanoes of Orosi and Cartago which have been the chief victims. This simultaneous action of the subterranean forces has also been noticed in the earthquakes in Venezuela, Peru, Chili, Mexico, and California. Very often, too, a close connection has been traced between the volcanoes in the islands of the Caribbean Gulf and the earthquakes of Central America, in the valley of the Mississippi, New Granada, and Venezuela. From the beginning of 1811 until 1813, a vast extent of land, bounded by the meridian of the Azores, the valley of the Ohio, the Cordilleras of New Granada, the coast of Venezuela, and the volcanoes of the Lesser Antilles, was agitated almost simultaneously by shocks which may be attributed to subterranean fires. Humboldt thus describes the series of

phenomena which seem to indicate the existence of communications at a great distance from one another. Upon the 30th of January, 1811, a submarine volcano made its appearance near the island of St. Michael, one of the Azores group. At first this was nothing but a shoal, but upon the 15th of June an eruption occurred, and lasted for six days, gradually raising this shoal to a height of thirty-three feet above the level of the sea. This new land, of which Captain Tillard forthwith took possession in the name of the British Government, calling it Sabrina Island, was about a mile and a furlong in diameter, and it has since been swallowed up by the floods from which it had emerged.

At the time of the appearance of this fresh islet, the Lesser Antilles, situated 2,000 miles to the south of the Azores, felt severe shocks of earthquake. More than 200 shocks were felt between May, 1811 and April, 1812, upon the island of St. Vincent, where stands the terrible volcano of Mount Garou. This motion was not confined to the West Indian islands, as on December 16, 1811, the land was several times shaken in the valleys of the Mississippi, Arkansas, and Ohio. These shocks were accompanied by a loud underground noise coming from the southwest. The whole of these phenomena lasted from

December 16, 1811, until 1813, and upon the former of these two dates the town of Caracas experienced a first shock, and upon March 16, 1812, was destroyed by a second and more violent one.

The volcano of the island of St. Vincent, more than 3,200 feet high, had not emitted any lava since 1718, and it was not until these earthquakes occurred that there was any sign of its being still active. But on the 27th of April, 1812, the volcano belched forth a lot of burning cinders, while on the 30th the lava streamed forth in torrents and rolled down to the sea, a loud underground noise following this outburst of fire.

On the 5th of April, there was a shock almost as violent as that of March 26th in the valley of Caracas, and upon the shore of the coast of the Guayra. At this moment, the shocks in the island of St. Vincent became more violent, but when on the 27th of April the volcano of Mount Garou burst into activity, the earthquakes suddenly ceased. The noise of this explosion resembled alternate discharges of heavy artillery and musketry, and a fact worthy of observation was that the sound seemed much louder out at sea, some distance from the island, than it did close to the volcano itself.

What proves the connection between the fires

of this volcano¹ and the earthquake shocks in Venezuela is, that upon the day of the great eruption of Mount Garou, upon the 30th of April, 1812, a panic was created through the upper valley of Caracas, as well as among the Savannahs and along the banks of the Rio Apure, over an area of 13,000 square miles, by a subterranean noise which resembled reiterated discharges of artillery. The sound was as loud upon the coast as at a distance of 250 miles inland.

In a straight line it is 650 miles from the volcano of St. Vincent to the Rio Apure, so that these detonations were heard at a distance equaling that of London from the Hebrides. This phenomenon, to which may be added a great number of similar facts observed in the Andes, proves not only that the sphere of the subterranean activity of a volcano is more extensive than is generally believed, but that the volcanic disturbance and the earthquake may be connected, even when the two phenomena, brought into being together in the depths of the ocean, are made manifest upon the surface at very remote distances from each other.

THE CATASTROPHE OF CARACAS.

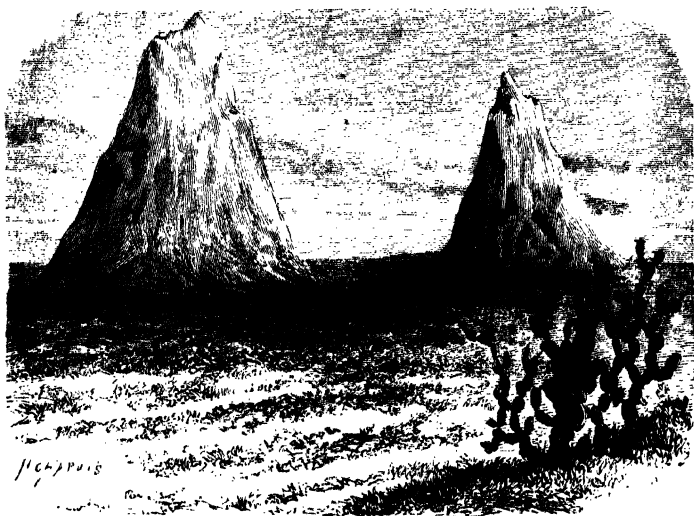
The upper valley of Caracas.—The town of Caracas before the catastrophe.—Suddenness of the earthquake.—Violence and duration of the shocks.—Destruction of the town.—Number of victims.—The tending of the wounded.—Magnitude of the disaster.

THE town of Caracas is situated in a very lofty valley, where reigns perpetual spring. The limited extent of the valley and the proximity of the lofty mountains of Avila and La Silla give a gloomy aspect to the site of Caracas, especially at the time of year when the temperature is coolest, viz. in November and December. The mornings are then very beautiful, and when the sky is clear the eye can discern the two domes or rounded pyramids of the La Silla and the jagged crests of Mount Avila. But towards evening the atmosphere becomes more dense, the mountains are veiled in mist and wreaths of mist hang over their verdure-clad slopes.

The cold air from La Silla forces its way down into the valley and condenses the light vapours into heavy fleecy clouds. But this sombre and melancholy aspect, this contrast between the serenity of the morning and the mists of the

evening, is not to be seen in summer, when the atmosphere retains its absolute transparency, and when the nights are clear and beautiful.

In 1812, Caracas was a large and handsome



The Upper Valley of Caracas, the two pyramids of the mountain of Avila.

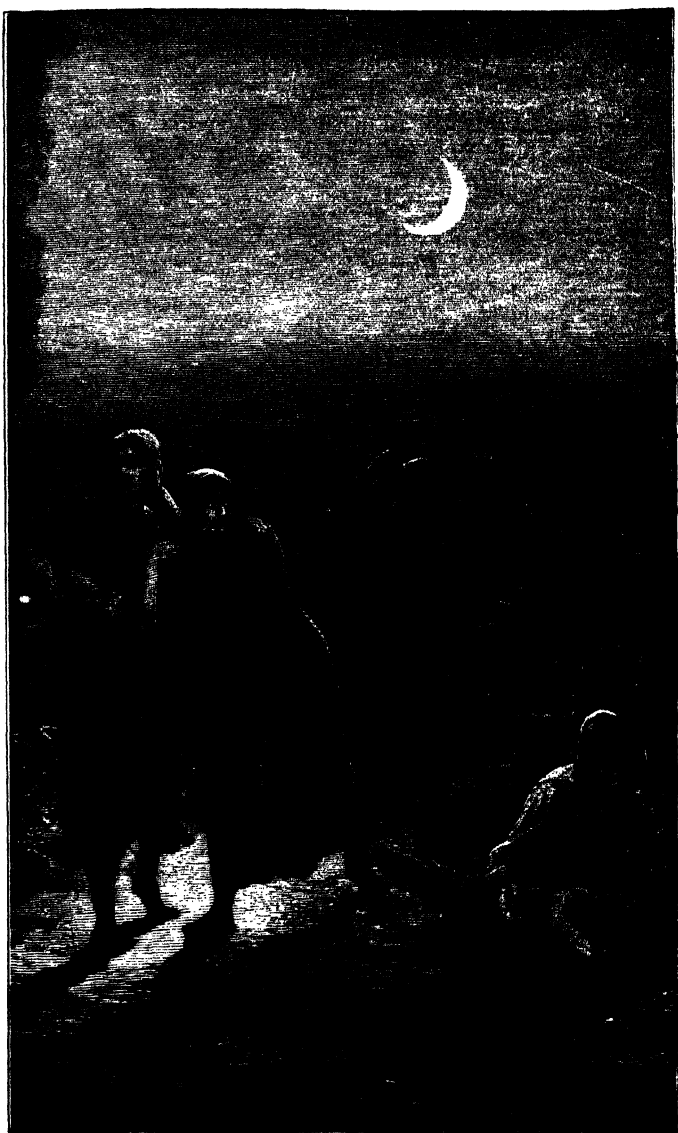
town, with wide and well-built streets, many churches and palaces, and fine houses built higher than is prudent in a country subject to earthquakes. The inhabitants of the upper valley of Caracas, unmindful of the subterranean shocks of Riobamba and other towns at a great altitude, deemed themselves secure in the structure of the rock and the great height of the valley. "It is

true," says Humboldt, "that religious festivals celebrated in the capital, such for instance as the midnight procession of October 21, instituted in commemoration of the great earthquake which occurred upon that date in 1778, at 1 A.M., reminded them from time to time of the earthquakes which had desolated the province of Venezuela, but dangers which only recur at rare intervals do not excite much apprehension.

In December, 1811, a violent shock, occurring when the weather was very still, broke the spell of this fancied security; and this was the only shock which preceded the terrible catastrophe of March 26, 1812, in which more than twenty thousand inhabitants perished in a trice. Alexander von Humboldt, in describing this mournful event, brings into relief several facts which cast an unexpected light upon the connection of subterranean phenomena.

People in Venezuela were unaware of the agitation which was going on, upon the one side in the volcano of the island of St. Vincent, and upon the other, in the basin of the Mississippi, where, on February 7 and 8, 1812, the land was night and day in a continuous state of oscillation. At this epoch, Venezuela was suffering from great drought. Not a drop of rain had fallen at Caracas or within 250 miles during the five months which preceded

the catastrophe. The weather on the 26th of March was very warm, the air was still and the sky without a cloud. It was the Thursday of Holy Week, and a great number of the inhabitants were at church. Nothing seemed to presage the impending catastrophe. At 4'7 P.M. a first shock occurred, and it was severe enough to make the church bells ring, lasting five or six seconds. It was at once followed by another shock, lasting from ten to twelve seconds, during which the ground, undulating incessantly, seemed to boil like liquid. It was thought that the danger had passed away, when a tremendous subterranean noise was heard. It was like the rolling of thunder, but louder and more prolonged than that which is heard in the tropics during a thunderstorm. Following this noise, came a perpendicular movement, lasting three or four seconds, followed by a rather more prolonged undulatory movement. These shocks were from opposite directions, from north to south and from east to west, and nothing could resist this double movement upwards and these intersecting oscillations. The town of Caracas was altogether destroyed. Thousands of the inhabitants were buried beneath the ruins of churches and houses. The usual procession had not yet started, but the crowd in the churches was so great that



NIGHT-TIME, AFTER THE CARACAS CATASTROPHE.

four thousand people met their death in them alone.

The shock was most severe in the northern part of the town, nearest to the mountain of La Silla, which rises like a vast dome, with steep cliffs in the direction of the sea. The churches of the Trinity and Alta Gracia, the latter of which was more than a hundred-and-fifty feet high, and the nave of which was supported by pillars twelve or fifteen feet thick, were reduced to a mass of ruins not more than five or six feet high. The subsidence of the ruins was such, that scarcely a vestige of pillar or column could be found. The barracks of San Carlos disappeared altogether, and a regiment of infantry, under arms to take part in the procession, was swallowed up with the exception of a few men.

Nine-tenths of the town was annihilated. The houses which had not collapsed were cracked to such an extent that their occupants did not dare to re-enter them. The cathedral, supported by enormous flying buttresses, held its ground. To the estimate of twelve thousand victims caused by the earthquake must be added the many who succumbed, weeks and months afterwards, for want of food and relief. The night of Holy Thursday to Good Friday presented the most lamentable spectacle of desolation and woe which

can well be conceived. The thick layer of dust, which, ascending from above the ruins, obscured the air like a mist, had again settled on the ground ; the earthquake shocks had ceased and the night was calm and clear. A nearly full moon lighted up the oval domes of La Silla, and the aspect of the sky was in striking contrast with that of a land strewn with corpses and ruins. Mothers might be seen running about with their children whom they were vainly trying to recall to life. Distracted families were wandering about in search of a brother, a husband, or some other relative whose fate was unknown to them, but who, they hoped, might have got lost in the crowd. The very appearance of the streets was so altered that they could only be identified by examining the character of the ruins which occupied their site.

The injured lying half-buried beneath these ruins were making piteous appeals for help, and more than two thousand were extricated. Never did human kindness reveal itself in a more touching and ingenious fashion than in the efforts made to relieve the sufferers whose cries were so heart-breaking to hear. There were no tools to clear away the rubbish, and the work of relief had to be performed with the bare hands.

The injured and the sick who had escaped from the hospitals were carried to the banks of the river

Guayra, where their only shelter was the foliage of the trees. The beds, the lint for binding up wounds, the surgical instruments, the medicines and all the objects of immediate necessity were buried beneath the ruins, and for the first few days there was a scarcity of everything, even of food.

Water also became very scarce inside the town, as the shock had broken up the conduits of the fountains and the upheaval had blocked the springs which fed them. In order to fetch water, it was necessary to descend to the river Guayra, which had risen to a great height, and there were very few vessels left to fetch it in.

It was necessary also to dispose of the dead with all dispatch, and in the impossibility of giving decent burial to so many thousand corpses, detachments of men were told off to burn them. Funeral piles were erected between the heaps of ruins, and the ceremony lasted several days. Amid so many misfortunes, the people resorted to the religious practices which they believed most likely to appease the divine wrath. Some of them marched in procession, singing funeral hymns; others, half demented, made a confession of their sins in the open streets.

Then ensued what had been remarked at Quito after the dreadful earthquake of 1797, and many marriages were solemnized between persons who

had hitherto not chosen to go through the wedding ceremony. Children were formally recognized by parents who had hitherto repudiated them ; restorations of money were made by persons never suspected of peculation, and long-standing enmities were forgotten in the sense of a common danger. Upon other natures, the sense of danger seems to have a hardening effect, and, as Humboldt remarks, vulgar minds are no more softened than they are elevated by a great calamity. Misfortune, like the study of literature and of nature, only exercises its refining influence upon a select few, imparting more warmth to the feelings, more elevation to thought and more benevolence to the disposition.

The fierce shocks which had in less than a minute occasioned such great disasters could not of course be expected to have confined their destructive effects to one narrow zone of the continent, and these extended to a great part of Venezuela, all along the coast and specially among the mountains inland. The towns of La Guayra, Mayquetia, Antimano, Baruta, La Vega, San Felipe and Merida were entirely destroyed, the number of deaths exceeding five thousand at La Guayra and San Felipe.

The shock was felt in New Granada, from the spurs of the lofty mountain of La Sierra de Santa Marta to Santa Fe de Bogota.

For fifteen or eighteen hours after the great catastrophe, the ground was perfectly quiet. The night, as I have said, was clear and fine, and it was only the next morning that the shocks began again, accompanied by a loud and prolonged noise. The inhabitants of Caracas dispersed into the country, but as the farms and villages had suffered equally with the town, they could find no place of refuge save by crossing the mountain and making their way to the Savannahs. The ground remained for several days in a continuous state of tremor, as many as fifteen oscillations being felt in one day. There were several large landslips in the mountains. Immense pieces of rock broke away from La Silla, above Caracas, and it was asserted that the two domes of this lofty mountain had fallen about 350 feet.

In relating the story of this terrible catastrophe upon his return to Europe, Alexander von Humboldt pointed out with sorrow that all his friends there had perished either in bloody revolutions or during the earthquake, but that a new town was already rising from the ruins of the old one. Since then the town of Caracas has become once more populous, and the capital of Venezuela is now one of the finest cities in South America.

AN EARTHQUAKE IN HONDURAS.

Volcanoes of Central America.—Frequency of the shocks.—The Lagoon of Criba.—Gust of wind and earthquake.—The waters of the lagoon are upheaved.—Immense column of water.

CENTRAL America is continually being disturbed by subterranean forces. Around the deep bays of this vast and splendid region, upon the shores laved by the waters of the Pacific, and also about the large inland lakes rise, like an army of giants, a number of lofty volcanoes. Whilst most of them are wrapped in a slumber which has lasted for centuries, others occasionally roar and groan as if in order to keep themselves awake and to watch well over their sleeping comrades. The fire which consumes their entrails extends far beneath the soil and often causes it to tremble. Three times within thirty years the town of Guatemala has been destroyed by earthquakes, and there is not, I think in all Guatemala, Honduras or any other State of Central America, a single coast which has not been visited by one or more violent subterranean shock. When the earthquakes occur in remote regions, far from the habitations of men, in the midst of virgin forests

or in the region of large lakes, they give rise to very singular phenomena.

In 1856, a painter, entrusted with an official mission in Honduras, witnessed an event of this kind, and though he has sought to conceal his



Waters of a Lagoon Upheaved During an Earthquake.

identity, he is generally believed to be Herr Heine, the well-known painter and explorer of Central America. Upon the day in question, he was sailing across a large lagoon named Criba, some twenty miles broad, the weather being calm and the sun shining brilliantly. After having secured his boat to the shore, he had landed at the

entrance to a beautiful little village commanding a view of the plain dotted with houses and with stately trees. Upon the opposite shore extended the forest, with the sea in the far distance. The chief inhabitant of the village having invited Herr Heine and his companions to come and rest, the whole party were seated beneath the verandah of the house, engaged in pleasant conversation. Suddenly a loud noise was heard in the forest. The birds flew off in terror, the cocoa-nut palms bent and writhed as if in panic and large branches of them snapped off; the shrubs were torn up from the ground and carried across the lake. All this was the effect of a whirlwind travelling through space from south to north. The whole affair lasted only a few seconds, and calm was re-established in Nature as suddenly as it had been disturbed. Conversation of course then turned upon the phenomenon just witnessed, and the natives maintained that atmospheric disturbances of this kind are the forerunners of severe earthquakes or violent volcanic eruptions; some of them maintaining that a catastrophe of this kind had doubtless just occurred somewhere or other. The host, an elderly man much esteemed in the district for his knowledge, went on to describe many such catastrophes which he had himself witnessed. He spoke more particularly of the eruption of the volcano of

Coseguina, in Nicaragua, which had been preceded by a fierce whirlwind. The whirlwind, he added, had been so strong that it carried pieces of rock and ashes to a distance of nearly a mile. The captain of a large sailing-vessel had told him that



An Emigrant and Vagrant Family, after an Earthquake.

upon the following day, when more than 100 miles from the coast, he had found the sea covered with pumice-stone, and had experienced great difficulty in threading a way for his vessel through these blocks of volcanic stone which were floating upon the surface like icebergs. Every one, including the European, had his story to tell, and while the

party were still in conversation, a terrible noise like thunder was heard, and the earth began to quake. At first the shocks were felt to be rising upwards, but after a few seconds they became transformed into undulations travelling northward, just as the sudden whirlwind had done. The soil undulated like the surface of a stormy sea, and the trees were rocked to and fro so violently that the topmost branches of the cocoa-nut palms came in contact with the ground and snapped off.

The large trees were only a few yards off, and yet it was impossible to reach them. There was a feeling as of walking in the air; at each step the ground seemed to give beneath the feet, and people fell full length, feeling at the same time very sick and giddy. The shocks followed in quick succession, but Herr Heine contrived, nevertheless, between the interval of two of them, to clasp the trunk of a large tree, to which he clung with desperation. At the same moment another and still more violent shock was felt, and upon the other side of the lagoon the whole forest was seen to sway. The largest trees were heard to crack, and, after swaying for a few seconds, came to the ground.

The traveller and his friends, believing themselves to be out of danger, were able to follow with ever increasing interest the rapid phases of

the disturbance, when a strange and alarming phenomenon attracted their notice. "Our attention was called," relates Herr Heine, "to a terrible commotion in the direction of the lagoon, but I cannot express what I then saw. I did not know if I was awake or a prey to a nightmare; whether I was in the world of reality or in the world of spirits. I found myself, in short, suddenly transported into such a marvellous region that even the sense of fear forsook me, and that I could enjoy at my ease the grandeur of the spectacle unfolded before me."

The water of the lagoon disappeared as if it was engulfed in a sort of subterranean cavern, or, rather, it turned over upon itself, so that from the shore to the centre of the lake the bed of it was quite empty. But in a few moments the water reappeared, and mounting towards the centre of the enormous basin, it formed an immense column, which, roaring and flecked with foam, reached so high that it intercepted the sunlight. Suddenly, the column of water collapsed with the noise as of thunder, and the foaming waves dashed towards the shore. Herr Heine and his companions would infallibly have perished if they had not been standing upon elevated ground, and, as it was, they could not restrain an exclamation of horror as they saw this mass

of water, like a solid rock rolling along the plain, carrying trees, large stones, and whole fields before it.

“I saw all that without at first thinking of our own fate,” recites Herr Heine, “and I think that the greatness of the peril which threatened the whole country made me indifferent as to the fate of myself and my companions. In any case, when I saw my familiar companion Carib nearly carried off, I remained indifferent, and it was only after two other of my followers, Manuel and Michel, had had very narrow escapes, that I succeeded in shaking off my apathy, and going to their assistance.” But just as Herr Heine saw that they had got safe, his strength failed him, and he fell senseless to the ground. When he reopened his eyes, he saw his friends around him, endeavouring to relieve him. Nature had regained her calm aspect of every day, the waters of the lagoon were at rest, and, but for the scene of desolation around, and the consternation of his companions, he might have thought that he had been the victim of feverish hallucinations.

11.

Aspect of a virgin forest after the catastrophe.—Destruction of the town of San José.—Emigration of the inhabitants.

When the travellers, whose boat had disappeared, started for the town of San José, whence they had come in the morning, they were able to judge for themselves as to the extent of the disaster. All the country which they had passed through had been laid waste. The underground shocks had brought the largest trees to the ground and had snapped off the thickest trunks like so many sticks. Large masses of rock had been detached from the mountains, and obstructed the course of streams which had overflowed their banks or changed their course. Whole villages had been destroyed, and in all directions arose the lamentations of the unfortunate inhabitants. The region over which the waters of the lagoon had been carried was no longer to be identified as the same, covered as it was with débris of every kind and with a thick layer of sand and rock. When they started in the morning, the travellers had left San José prosperous and full of cheerful stir, but when they returned at night, they found it in ruins, and almost deserted. The earthquake had upset all the houses with the exception of about twenty, and these were very badly damaged.

All the buildings in solid masonry, including the massive church, were mere heaps of ruins ; most of the inhabitants had perished, and the survivors, kneeling among the ruins, were grouped



Inhabitants of San Salvador on their knees during the Earthquake.

around the clergy, who told them that this was a visitation sent by God, and exhorted them to penitence.

Men, women and children were so absorbed in lamentation and prayer that they did not think of bringing relief to those who were lying in

agony beneath the ruins, and whose groans were so painful to hear. The Indians who were prowling in the outskirts of the town took advantage of the inhabitants being absorbed in prayer to enter the town, and carry off all they could from the houses which were still standing and from the ruins of the others. The agility with which these Indians move about among the ruins and escape the falling walls is something wonderful, and they never hesitate to risk their life for a very trifle. In Central America, disasters of this kind almost invariably cause the inhabitants to emigrate. Men, women and children form themselves into groups, and travel through the country. They set the drama in which they have taken part to music, and they go through the country, singing the rude verses which they have run together in the different villages, and then sending the hat round. After they have visited the whole of their own country, they cross the frontier into the neighbouring State, where they are also assured of doing pretty well. Thus for more than a twelvemonth Honduras and Nicaragua were visited by bands of homeless victims, chanting in a monotone the eruption of Lake Criba and the terrible catastrophe of San José.

THE CATASTROPHE OF SAN SALVADOR.

LIKE all the Spanish towns in America, San Salvador, capital of the republic of that name, covers a large area in proportion to its population. The houses are low, none of them having more than one story, while the walls are very thick in order to be capable of resisting earthquakes. Inside each house is a courtyard planted with trees, generally having a fountain in the centre. It was to these spacious courtyards that in 1854 the inhabitants of San Salvador owed their lives, as they found in them a refuge from their falling houses.

San Salvador, which then had a population of about 25,000, had already suffered several times from oscillations of the soil, earthquakes having occurred there in 1575, 1593, 1625, 1656, and 1798; while a shock took place in 1839 which destroyed almost the whole town, and the inhabitants were near leaving it in a body. The volcano at the foot of which the town is built had also threatened to destroy it once or twice; but the inhabitants, accustomed to slight shocks,

were wrapped in complete security and made fun of the "old moles," as they called them, who had established their dwellings underground. Still, San Salvador had been so continuously disturbed by earthquake shocks that it had acquired the name of "the hammock." The inhabitants were startled from their sense of fancied security when the shocks, suddenly changing their character, gave place to furious paroxysms, and the swinging of the hammock was transformed into a scene of devastation which the pen is powerless to describe.

A remarkable circumstance which characterizes the great earthquakes of Central America, and of which we have documentary evidence, is the periodic recurrence of the shocks. The library of Guatemala contains printed documents relating to the catastrophes which have ravaged the country for the last three centuries, and they show that when these great disturbances have occurred, the first and fatal shock has invariably been followed, during a period of several weeks, by more or less violent shocks.

But none of these catastrophes had more disastrous effects than the earthquake in question. The terror which it created in men's minds was such that after the catastrophe, the population, being afraid to return, suggested choosing another

site for the capital, as had been done in the case of Guatemala, which, at first stood upon the site now occupied by Antigua (or the ancient city), but which was almost entirely destroyed by earthquake in 1773. It is scarcely probable that this earthquake, severe as it may have been, was more so than that which destroyed San Salvador. When the Caracas earthquake took place in 1812, it will be remembered that there were three shocks, each of which lasted several seconds. San Salvador was destroyed by a single shock, which, as Squier in his "Notes on Central America" tells us, lasted only ten seconds.

The night of April 16, 1854, will remain a sad souvenir in the memory of the inhabitants; for, during this fatal night, the bright and beautiful capital was laid in ruins. The first motions of the soil, preceded by a sound like that of the rolling of artillery upon the pavement, or the distant muttering of thunder, were felt in the morning of Holy Thursday. This phenomenon alarmed the inhabitants, but did not prevent them from assembling in the churches to take part in the services of the day. Up to Saturday, there was nothing to cause alarm, and people met as usual to celebrate the festival of Easter. All remained calm during the night of Saturday to Sunday. The heat, it is true, was very great, but the

atmosphere was pure and limpid. Nothing unusual occurred during the early part of the evening, but at half-past nine a severe shock, which had not been preceded by any of the sounds usually heard, created great consternation among the inhabitants. A number of families left their houses and camped out in the public squares, while others prepared to pass the night in the courtyards of their houses.

At ten minutes to eleven, without any preparatory phenomenon, the earth began to quake so violently that the town was laid in ruins at the first shock. The houses and churches fell in with a terrific crash; a cloud of dust arose from the ruined houses, and enveloped in its darkness the inhabitants, stricken with terror; the wells and fountains were either choked or dried up, and there was not a drop of water to give to the half suffocated victims. The tower of the cathedral fell in and destroyed a great part of the building, while that of the church of San Francisco crushed in its fall the oratory and the bishop's palace. The church of Santo Domingo was buried beneath the fragments of its towers; the college of the Assumption was entirely destroyed, and the newly built university was demolished; while the church of La Merced was riven in the centre, the walls falling out upon each side. A few houses remained

standing, but all of them became uninhabitable, and it is worthy of remark that the old walls alone resisted the shock, all the new ones coming down. Public buildings as well as private houses were destroyed.

As I say, ten seconds sufficed to produce this terrible disaster. The shocks which followed were very severe, too, and were accompanied by frightful underground rumbling ; but they did not, by comparison with the first, do much damage.

The spectacle was a very sad one, what with the people on their knees imploring the Divine pity, crying piteously for their relatives whom they feared were buried beneath the ruins ; with the sky opaque and sinister-looking ; with the rapid and irregular motion of the soil causing indescribable terror ; with a strong odour of sulphur filling the atmosphere, and threatening an eruption of the volcano : with the streets obstructed by falling walls and chimneys ; and with a cloud of dust which choked those who were wandering about.

A hundred children were shut up in the school ; the hospitals were full of patients, and the barracks of soldiers. The idea of the dreadful death from which all these unfortunates could not escape took possession of the public, but the members of the Government were able in a measure to re-assure

them, as it was soon found that the victims, were not so numerous as had been expected. Among the injured was the bishop, who had received a severe blow on the head, and President Queñas, who was also badly hurt. The earthquake was fortunately not followed by rain, so that there was no difficulty in saving from out of the ruins the public archives, and many valuable objects.

The motions of the ground lasted a long time, and the inhabitants, fearing that the soil upon which the town stood would be swallowed or covered with lava from the volcano, fled in haste, carrying with them their household goods, their cattle, and the tender recollections of their childhood. This was all that remained to them, and they could say with Virgil,—

“*Nos patriæ fines et dulcia linquimus arva.*”

Maurice Wagner was at San Salvador at the time of this terrible catastrophe. He relates that the moon was shining brightly, when suddenly a sinister sort of light was shed upon the site occupied by the capital. It was the whole city which was collapsing. This German traveller goes on to say :—“ When I reached the square, lighted up by the pale rays of the moon, a strange sight awaited me. A crowd composed of all classes of society

was assembled there, kneeling in prayer, and groaning. Ancient patricians, descendants of illustrious Creole families, were side by side with persons of the lowest rank. Very pitiable was the condition of the women, who, overtaken by the catastrophe while asleep, had scarcely time to wrap a sheet around them."

Amid this scene of terror an Indian might be seen here and there among the ruins, and laying hands upon anything of value he could find. Terrified by a fresh shock, which caused the walls still standing to rock, the Indian marauders rushed like ghostly forms from their hiding places, and united their prayers to those of the inhabitants, for the Indians are fervent Christians when they are in fear of death. But once the moment of danger is over, their plundering propensities regain the mastery; and so, while the inhabitants of San Salvador were full of anxiety about the safety of themselves and their friends, the Indians were left free to pillage and plunder to their hearts' content. The unfortunate city was not only destroyed, but all moral restraint was gone, and government, justice, police, and clergy had all disappeared. The crowd was gathered in prayer around the ruins, but no priest was there to give them courage or hope. Herr Wagner says: "Don Thomas Soldanna, the bishop of San Sal-



INDIAN MARAUDERS LOOTING AMONG THE RUINS OF SAN SALVADOR. p. 156.

vador, venerated by the people as a saint, had been unable, owing to his great age, to leave his palace, and was found lying on the ground badly injured about the head. When he came to himself he lost all self-possession, and was the first to give the signal for flight, declaring that God had given the city over to the power of the Evil One, as a punishment for its sins, and that, in spite of the name it bore, it would be cast into the bottomless pit." Then followed a general rout, and before daybreak the bishop and his clergy had fled in the direction of Cajutepec.

It was feared that in this critical state of things there would be a renewal of the civil war, which had devastated the unfortunate Republic for so many years ; but at this conjuncture a man endowed with great presence of mind and rare energy came forward and saved the country from this peril. Don José Francisco Dueñas, who had been in turn a monk, a lawyer, a deputy and president of the Republic, and who had since been living in retirement upon his farm, summoned a few of his most trustworthy friends to meet him in the market-square. They collected all the arms they could find beneath the ruins of the barracks, and Dueñas, though himself badly injured about the head, was able to impart some of his own energy to the newly elected president

José Maria San Martin. He got together a troop of fifty men, who patrolled the streets, despite the constant recurrence of the shocks. Every person caught in the act of pillage was at once tried and shot, and when the marauders heard the rattle of the musketry, they either made off for the country or were very careful as to what they took. The fear of death was stronger than the love of gain, and thousands of Indians came to offer their services in recovering the valuables buried beneath the ruins,

Maurice Wagner, forsaken by those who had accompanied him, a stranger in the place and suffering from intermittent fever, returned, on Easter Monday, the day after the catastrophe, to the *chacara*, or small country house, of the vice-consul of Prussia. "This villa" he adds, "was situated in a charming valley watered by the Rio Asselhuate, near a thermal spring overshadowed by a belt of palms. I had left this dwelling the day before the catastrophe; but what a change these few hours had wrought! The master of the house had fled to Apopa with his family and servants; the walls alone were standing, and many of them were full of large cracks, while part of the roof had fallen in. The palm-trees had been much damaged, and the earthquake shocks had brought down from the overhanging mountains

large fragments of rock which had blocked up the bed of the stream. The whole scene was one of utter devastation."

The terror of the situation was intensified by the panic which possessed the population even when the intensity of the shocks diminished. As soon as it was learnt that Apopa, a large Indian village situated about ten miles to the east of San Salvador, had escaped the visitation, thousands of people made their way there, while a great many others went off into the country, in the wake of the clergy, believing that they would be safer near them than anywhere else.

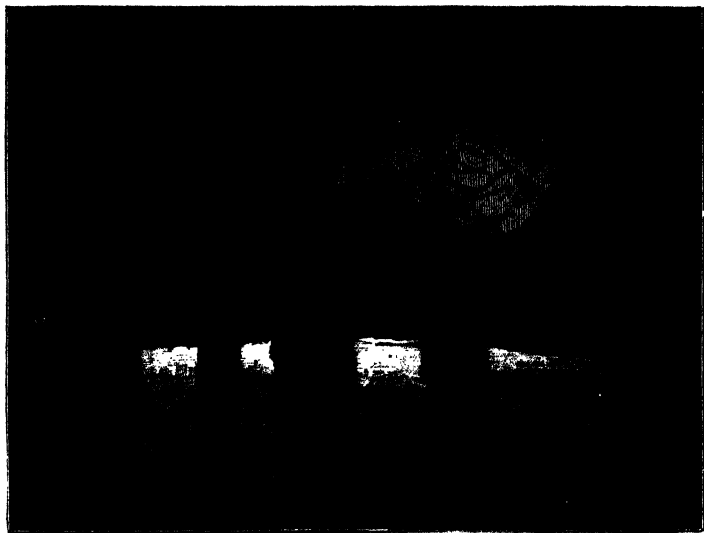
HOW THE EARTHQUAKE EXTENDS.

Motion of the soil at the centre of the shock.—Terrestrial waves running parallel with mountain chains.—Velocity of the waves athwart rocks.—Wells and grottoes weaken the shocks.—The wells of the Capitol.—The crevices and grottoes of Quito.

THERE is a distinction to be made, upon the one hand, between the initial force which determines the vibration of the soil, and, upon the other hand, the nature and propagation of the waves of disturbance. It is much easier to reconcile with simple and self-evident theories of mechanics the motion of the terrestrial waves, produced by the first impulse, than it is to explain the nature and origin of this impulse. In nearly every case, the earthquake shock is vertical at the point where the maximum violence of the shock is felt, the soil moving alternately upwards and downwards, and *vice versa*. Around this central point, as I have already said, the movements are more on the incline, and as they spread through the subterranean strata, they assume a nearly horizontal direction, concurrently with becoming less violent. At the moment of a severe shock, the terrestrial waves may be felt passing

rapidly beneath one's feet, so that it is easy to note from what direction they come and towards what point of the horizon they are moving.

The undulatory movement does not always



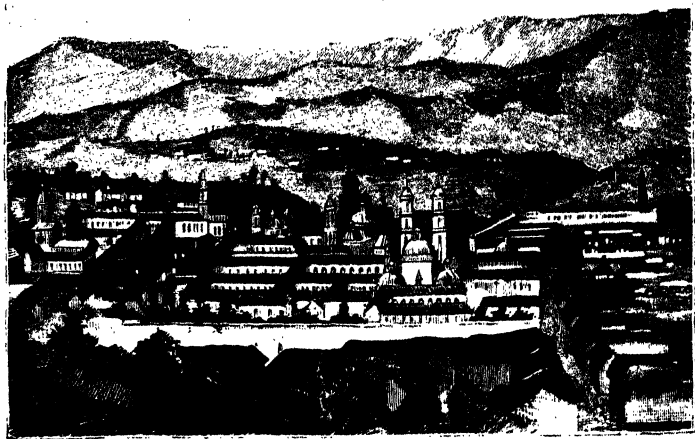
Underground Grotto giving way.

continue upon what would seem to be its normal course. Obstacles within the interior of the earth, local conditions scarcely possible to be determined, sometimes interfere with the regular spread of terrestrial waves, and produce ruptures which cause the earthquake to turn sharp off in another direction. Thus it has been noticed that the waves of disturbance, when they come in contact

with an elevated shore or the substratum of a mountain chain, generally alter their course and skirt the coast or mountain in the direction of the valleys, just as the waves of a river follow the level of the ground against which they may strike.

But if the rocky bed of great mountains interferes with the subterranean undulation, it does not offer an irresistible barrier to its progress, as is commonly believed ; on the contrary, the waves of disturbance, after rippling, so to speak, all along the mountain range, eventually penetrate right beneath it to the opposite slope. It is not merely the shape or relief of the soil, it is not merely the more or less upright strata of the mountain ranges which impel, alter or impede the movement of the terrestrial waves, but it is also the nature of the rocks which they traverse. It is the same with the waves of subterranean disturbance as it is with those of sound. We all know that certain substances arrest while others facilitate the transmission of sound. Rock, wood, metals and water propagate the undulations of sound much more rapidly than air or gas ; the average velocity of the sound-wave being 1,560 yards a second in water, and 3,858 yards in a bar of iron, while it is only 366 feet in the air. In the same way, the velocity of the propagation of the subterranean waves varies according to the

geological composition, the hardness and the elasticity of the rocky strata which these waves encounter and have to traverse. They spread much more easily and much further through hard and



The Town of Quito, Ecuador.

compact rocks than through porous rocks, strata of sand or loose land in which there are crevices, fissures or caverns. Robert Mallet made some very ingenious experiments, by which he found that the waves of disturbance, set in action by the explosion of a powder mine, travelled at the rate of 316 yards a second in moist sand and 545 yards a second in granite rock.

It has been remarked that fissures, grottoes and even wells lessen the violence of the subterranean waves. This fact had not escaped the sagacity of the men of old who inhabited the regions of Greece, Italy and Asia, which were full of caverns, crevices and underground rivers. Nature, in its uniform progress, everywhere gives birth, as Humboldt remarks, to the same ideas as to the causes of earthquakes and the means by which man, oblivious of the limits of his strength, seeks to lessen the effect of the underground disturbance. Pliny, the naturalist, advised the digging of caves and wells to break the violence of the shocks. It is said that the Romans, when building the Capitol, did this, and that to this is due the preservation of that monument for so many centuries. The Italians believe that if the town of Naples, situated at the foot of Vesuvius, has not suffered more than it has from earthquakes, it is solely because the houses are built over deep and broad cellars.

At Santo Domingo, as well as in Central America and Mexico, no one doubts but what grottoes and mines lessen the shock, and the immunity of Quito, the capital of Ecuador, is attributed to its being built upon ground intersected by numerous caves and quarries. Pliny's observations as to the usefulness of wells and

caverns (Book II., Chapter LXXXII.) as a protection against earthquake shocks is repeated in the New World by the most ignorant of Indians, when they show travellers the *guiacos* or crevices of the volcano of Pichincha, at the foot of which is built Quito, 9,496 feet above the level of the sea. This large town contains many a handsome cupola and lofty church, together with massive houses of several storeys. Although earthquakes are of frequent occurrence, there is rarely a crack to be seen in the walls, while upon the plains of Ecuador oscillations much less violent do damage even to bamboo huts rising very little above the ground.

II.

Central earthquakes.—Linear earthquakes.—How their waves skirt obstacles in the way.

IF lines be drawn upon a map connecting the different regions over which an earthquake has gradually extended, starting from the nucleus of the disturbance, a figure or zone will be obtained indicating the mode in which the subterranean phenomenon has been propagated. Sketches of this kind have been made with extreme care by the most able seismographers in all countries, and

the general outcome of their patient researches goes to show that earthquakes spread in two ways.

Sometimes the disturbance extends from its starting-point over a space of ground which forms an ellipse or a circle, in which case you have a central earthquake. Such, for instance, was the Lisbon earthquake, the waves of disturbance extending over an area equal to an eleventh part of the earth's surface. The central earthquake is, moreover, the more frequent, and it is the one whose waves as they spread are similar in character to the waves raised upon the surface of water by throwing a stone into it.

At other times the disturbance, starting from the central point, covers a narrow zone, spreading out lengthwise like a ribbon. In this case you have the linear earthquake, the waves of which generally follow the level of the valleys, parallel with the mountains. Such, to give but one instance, are the earthquakes of South America, which, in New Granada, Ecuador, Peru and Chili, generally spread along the western slope of the Andes, and in Venezuela along the slopes overlooking the Indian Ocean.

Sometimes the linear earthquake, after having spread over a single zone, divides into several sections, as if it had been broken off by some

underground obstacle. In this case it continues to spread in several lines or parallel strips, just as a river divides into several arms, in order to turn or traverse the obstacle in its way.

III.

Difficulty of giving with precision the average speed of the terrestrial waves.

As the diversity of the rocks, the relief of the soil, and many other unknown causes may delay or facilitate the propagation of the waves of disturbance, it is impossible to say what their mean speed is. A different speed has been noted for each earthquake. According to Mitchell, who has studied these phenomena very carefully, the waves of disturbance at the time of the Lisbon earthquake, travelled at the rate of eighteen miles a minute. Jules Schmidt, astronomer at the Bonn Observatory, computed, in reference to this same earthquake, that the speed was five times greater between the coasts of Portugal and North Germany than along the Rhine. This same astronomer was able to ascertain, too, that when the earthquake of 1846 occurred in the basin of the Rhine, the rate of speed at which the waves travelled was 492 yards a second, or more rapidly than sound waves in the atmosphere.

It is said that the shock which was felt in Guadeloupe and other of the West Indian islands in 1843, traversed the bed of the West Indian Ocean at a speed of 720 miles a second.

The electric telegraph provides an almost certain and always practical method of determining the speed of waves of disturbance. It was, I think, in 1853, that it was applied for the first time in a regular manner to signalling shocks of earthquake. Thanks to it, the speed of the terrestrial waves during the earthquake shock of 1855 in the valley of Viège was ascertained almost to a nicety, being at the rate of 960 yards a second, from the valley of Viège to Strasburg, and only half that in the direction of Turin, the nature of the rocks and the relief of the soil having offered greater resistance to the propagation of the subterranean waves.

IV.

Simultaneousness of the shocks.—Earthquakes occurring at the same time in places very far apart.—Is there a connection between them?

EARTHQUAKES, as the numerous facts which I have mentioned prove, sometimes extend over a very wide surface. From the centre of the disturbance, that is to say, from the spot at which

the first shock occurs, the vibrations go on extending from one subterranean stratum to another for tremendous distances, just as upon the surface of the water, the waves, raised by the fall of a stone, go on extending from the centre of the disturbance, and only die out when they have travelled a long distance. It will be seen that in my mind the shocks which disturb so many distant countries at the same time constitute a single earthquake, one vast subterranean phenomenon. But, it may be asked, is this mode of solving the problem in conformity with facts? A few instances will be of interest as illustrating this question. Let us take the Lisbon earthquake of 1755; the suburbs of that city, or more strictly speaking the Portuguese coast at the mouth of the Tagus, is regarded as the centre of the disturbance, because it was there that the most violent shocks were at first felt.

At the same time that Lisbon was being laid in ruins, the ground trembled in Sweden, and along the African coast, and westward it was disturbed upon the other side of the Atlantic Ocean. The question is as to whether the shocks in Sweden, Africa, and America, were echoes of those felt in Portugal. Several men of science, including Otto Volger, who has studied with so much care the earthquakes of Central Europe, say not, re-

garding all these shocks as so many isolated disturbances, having no connection the one with the other, while others regard them all as part of one whole. I share the opinion of the latter, on the ground that whole localities, districts and regions, situated between Lisbon and these extreme points, were disturbed at the same time. Between Sweden and Portugal there were earthquake shocks in France, Switzerland and Germany; while, between Portugal and America, the bed of the ocean was felt to rock, as well as the island of Madeira. Although vast regions remained motionless in the very centre of the zone which was disturbed, it is none the less true that the shocks felt north, south, and west were so many links connecting these extreme points with the centre of disturbance. Is it not, therefore, natural and even compulsory, to recognize the close connection of all these disturbances, and to consider the whole phenomenon as one single earthquake, extending over a considerable part of the terrestrial surface?

But it sometimes happens, too, that shocks occur simultaneously at two points of the globe, very far from each other, without there being anything to show, by way of a link between the two commotions, that other countries have been disturbed at the same time.

The earthquake which ravaged New Granada in 1827 is a remarkable instance of the simultaneousness in question, for upon the 16th of November the terrible scourge desolated the whole of the splendid table-land of Santa Fé de Bogotà, and at the same hour several violent shocks were felt at Ochotok, in Siberia, at a distance of more than 7,000 miles. Let me give a second instance. An earthquake occurred on the 19th of January, 1850, at Chutchá, a small town in the Caucasus Mountains, and at the same instant severe shocks were felt in Chili and California. It would be easy to cite a great number of analogous cases, but those given will suffice to show that subterranean disturbances sometimes occur with equal violence and simultaneously in countries far apart from one another, without its being possible to establish any *point de repère* which connects one with another. In these cases it is impossible to say positively whether there are two distinct shocks which take effect simultaneously at the two extremities, or whether there is one single shock, which extends and propagates itself below ground to depths beyond the possibility of measurement, to come up again on the surface at the two extreme points. It has been, moreover, observed that when a severe earthquake occurs, vast tracts of country remain undisturbed, while

the earth all around them is in commotion, so that they resemble islands in the midst of a stormy sea. Humboldt remarks in this connection that the subterranean waves, when they follow a coast-line or the base of a mountain chain, seem to expire when they reach certain places, and that this has been so for centuries. Not that the disturbance ceases, for it descends deeper into the bowels of the earth, instead of being apparent near the surface. This phenomenon is often noticed in Mexico and South America in the case of earthquakes which follow a given direction. The inhabitants of the Andes describe the region which enjoys immunity from the vibrations, as forming a bridge (*hace puente*), as if to signify that beneath the tranquil surface of this region the commotion is going on at a much lower depth, and eventually rises again to the surface,

V.

At what distance from the surface do the shocks originate?—
The method employed for fixing this distance.

It is clear that the focus in which these destructive forces are generated and developed is situated very far down in the bowels of the earth. It has been sought to determine this distance by

a calculation based upon the intensity of the disturbance and the distances which the subterranean waves have travelled; and in the earthquake of Viège, this depth was estimated at three miles, while in others it has been put at as much as twenty. All this, however, is purely conjectural; though, without being able to calculate the distances precisely, there is no difficulty in forming a good rough guess.

It is easy, for instance, to understand that the trepidations of the soil which take place in the immediate neighbourhood of a volcano must proceed from the centre of this lava, and that it is from the depths of the fiery crater that the elastic fluids which cause the soil to tremble at the foot of the mountain must proceed. With regard to the earthquakes which occur far from the volcanoes, but which are, like them, the results of caloric or subterranean heat, they must have their origin at a depth at which the subterranean heat is sufficiently intense to liquefy the rocky substances, and to impart to the vapour of water which penetrates into these abysses sufficient tension to enable it to raise up the matter in fusion and force it towards the surface. This depth cannot be less than ten miles, and Sartorius Walterhausen, who devoted much attention to the study of volcanic phenomena, put it at no less

than 78 miles. These, then, would seem to be the varying depths in which generate the gases and the fiery vapours which, as they permeate the masses of rock, drive them upwards, and produce the terrible earthquakes, such as those in Chili in 1822 and 1835 when a whole coast was suddenly upheaved, or that of 1839 when the country about the mouth of the Indus was completely changed in shape.

VI.

Land prone to be disturbed.—Why buildings of stone and masonry cannot withstand violent shocks.—The best way to build houses in regions prone to trepidation.

It has been noticed, too, that buildings erected upon a sandy soil, which itself rests upon a compact rock, are more easily overturned than those built upon the living rock itself, though the latter, under the action of the terrestrial waves, vibrates more readily than friable soil. This is analogous to the effect produced if a thin layer of sand is placed upon a sheet of glass. If the sheet is made to vibrate, the sand, which is not cohesive, will be seen to shake violently. When an earthquake occurs, each point of the surface of the soil begins, at each distinct vibration, to move upwards, then forwards, then downwards, and finally back-

wards. This series of motions forms an ellipse, which is repeated each time the wave arrives, and as long as the shock lasts. When the longest axis of the ellipse is directed upwards, that is to say when the movement upward and downward is strong and distinct, the shock is a vertical one ; when, upon the contrary, the lateral motion, that is to say the one directed forward and backward, predominates, the shock is an undulatory one.

The destruction of buildings is due to their inability to follow these motions. Their great weight makes them very inert ; that is to say, some time must elapse before the movements of the soil can be imparted to them. Consequently, when the foundations are carried forward, by the undulating motion of the soil, the upper part of the building remains behind ; when the earth returns to its place, the upper part begins to move forward, but the foundations regain their normal position, so that the walls are cracked and split by the tension produced between their constituent parts. They fall to pieces because their cohesion as a solid mass is almost null as compared to their weight.

When the shocks take place chiefly in an upward direction, it is the roofs which suffer most, for during the ascending motion the walls are forced upward, but the roofs and heavy

floorings are left behind, and fall in upon the occupants of the house. So that in countries subject to earthquakes, it is advisable to build houses of no great height, with massive walls and light roofs, as is done in St. Domingo and all parts of Central and Southern America. But buildings of stone and masonry must be, in spite of the most minute precautions, at the mercy of the earthquake, while those of wood nearly always resist, as the timber unites strength with lightness, and cohesion with elasticity.

The buildings which suffer the most are those crowned by domes or cupolas. At the first vertical shock, these latter collapse inwards, and cause to bulge outwards the walls within the circumference of which they come down ; and this is why churches so often suffer more than any other building, and why the masses of penitents who flock to them, in the hope of propitiating an offended Providence, are the first victims of the earthquake.

As Robert Mallet observes, it is to earthquakes, rather than barbarians, from the fifth to the ninth century, that Rome owed the loss of so many superb palaces and temples. One might imagine that in these great disasters, the architect is the ally of the subterranean scourge. The Indian's hut, and the Arab's tent, may be over-

turned without any great loss or injury to their owners ; but the marble of the patrician crushes him as it falls, and the inhabitants of a great city meet their death under the ruins of their sumptuous buildings. The Peruvians of old were not far wrong in making merry at the folly of their Spanish conquerors who, in erecting buildings upon a soil so constantly agitated, were preparing at great expense their own tombs.

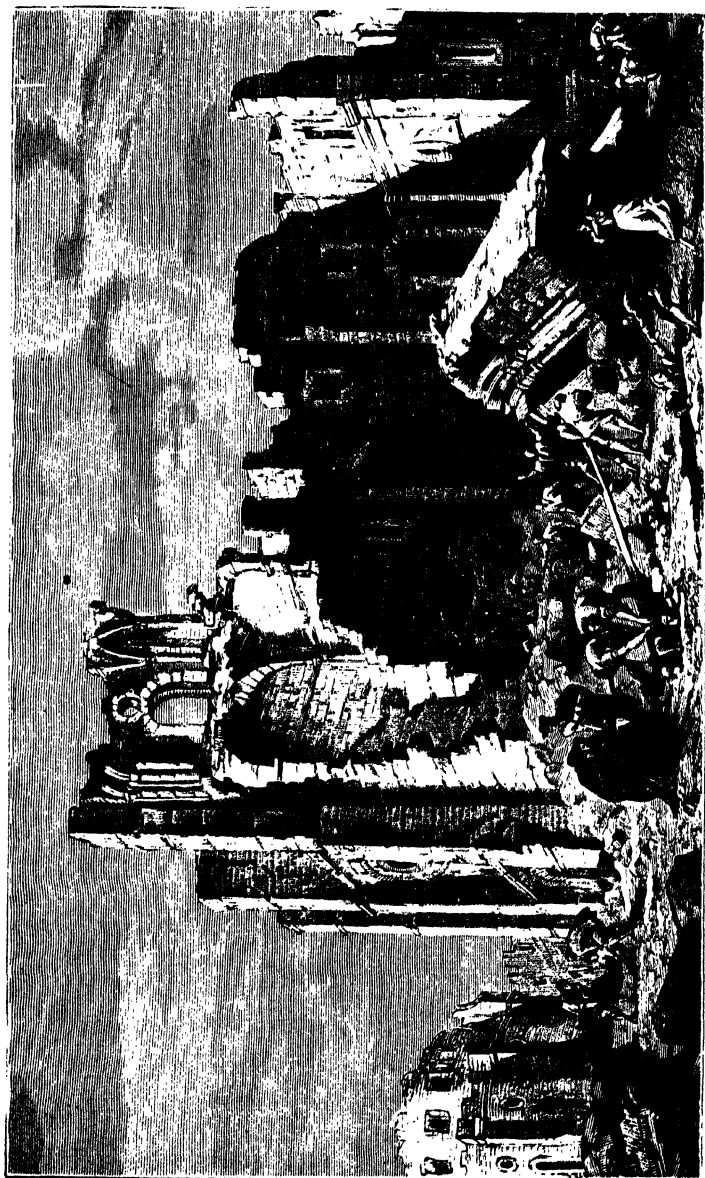
THE LISBON EARTHQUAKE.

I.

Three shocks destroy Lisbon.—All Saints' day.—The numerous deaths in the churches.—Aspect of the city in ruins.—The bed of the Tagus is upheaved.—Falling in of the principal quay.—Tumultuous motion of the sea.—The King at Lisbon.—Flames and smoke.—Oscillations of the soil in Spain.

UPON the 1st of November, 1755, at 9.35 A.M., the weather being magnificent, a terrible shock, accompanied by a loud underground noise, suddenly shook Lisbon to its foundations. This first shock did not last more than five seconds, but it overturned the finest buildings in the city, including the principal churches and convents, the royal palace, the opera-house, and many houses. This first shock was followed at an interval of two minutes by two other shocks which completed the ruin of the opulent city. The earthquake, with its three shocks, lasted five minutes, and when the third shock was over 40,000 persons were either dead or dying.

The lofty steeples and roofs of the churches were the first to fall in, and as this was All Saints' day and the hour of high mass, the havoc wrought was very great. All those parts of the town built



upon friable soil were completely destroyed, but in the few parts of the town where the houses were built upon the rock, they offered more resistance, though most of these were so much damaged that they came down afterwards. The heart-rending sight of the corpses and the groans of the dying so terrified the survivors that they thought more of their own safety than of relieving the injured. Moreover, it was no easy matter to rescue them, seeing that all the apparatus for so doing had been swallowed up. There was soon a crowd of weeping men and women scouring the streets, and crying aloud for their missing relatives in most piteous accents.

Several people who were in a boat upon the Tagus, about a mile-and-a-half from the town, felt a violent shock, as if their boat had run aground, though they were in mid-stream, and at the same time they saw the houses on each bank falling in.

The bed of the Tagus was upheaved in several places to the level of the water, and vessels, wrenched violently from their moorings, were driven against each other with a loud report. The great marble quay, Cays de Prada, sunk beneath the waters with several thousand people who had taken refuge there, and a great many boats moored to this quay and full of people

disappeared at the same time. As none of their bodies, nor any fragments of the boats or of the quay itself, ever rose to the surface, it is probable that quay, boats, and people were all swallowed up in a yawning abyss which at once closed upon them.

The sea suddenly receded, and the bed of the harbour was quite dry, but suddenly an enormous wave more than fifty feet high appeared, and seemed as if about to inflict a still greater disaster upon the unfortunate city. The bay, however, within which the tidal wave burst, is so large that the first force of it was broken, though the waters reached such a height in the houses still standing, that the survivors were obliged to take refuge in the upper storeys.

A final shock was felt about twelve o'clock, and many walls were seen to open and close again at once, leaving scarcely a trace of the enormous fissure that had been made.

At this moment, that is to say about two hours after the earthquake, flames were seen to shoot out of the ruins, and the fire soon spread, a very high wind having sprung up, calm as the air was before and during the shock. This was probably caused by the fires lighted in the kitchens which had been thrown into contact with combustible matter of all kinds, and the result was that houses

which the earthquake had spared, and many of the injured lying among the ruins, were consumed by the flames.

“All the elements seemed combined to destroy



A Ruin in Lisbon, 1755.

us,” wrote Surgeon Wolsall a few days after the calamity to the Royal Society of London. “It is possible that the cause of all these disasters may come from the bottom of the ocean, for I have been conversing with a very intelligent

merchant-captain, who tells me that while fifty leagues out at sea, he felt such a violent shock that the upper deck of his vessel was very much damaged. He supposed that he must have made a mistake in his reckoning, and that his ship had struck upon a rock. Thinking she was sinking, he put down the boats in order to save the crew, but he eventually succeeded in bringing his vessel damaged as she was, into port."

The day following the catastrophe the king hastened back to Lisbon to initiate a system of relief, and the provinces at once came to the help of the sorely tried capital. The injured, of whom there were an immense number, were well cared for, and all the needy were kept at the expense of the State.

In the months of November and December several less severe shocks were felt in Lisbon and the neighbourhood, though upon the 9th of December there was a shock almost as severe as the first one. After three months of intense anxiety, when the shocks had ceased, the government began to re-build the town, and in fifteen years' time it was entirely restored, being now one of the finest in Europe.

The oscillations were almost as severe at Oporto as in the capital. At 9'40 A.M., the sky being as clear as at Lisbon, a terrible sound was

heard, like the rattling of many carriages over a rough road ; and, almost immediately afterwards, there came a shock which caused all the houses in the town to tremble. The walls of several churches cracked, and the ground quaked violently.

The Tagus was in such a state of agitation that its waters fell five or six feet in two minutes, and an enormous quantity of gas escaped from them. The town of Setubal, situated at a distance of 17 miles from the Tagus, and 22 miles S.E. of Lisbon, was almost entirely swallowed up.

The highest mountains in Portugal were shaken to their base, their summits were overthrown, and large masses of rock were toppled over into the valleys. At a distance of 17 miles from Lisbon, near Colares, flames and a column of thick smoke were seen to issue from the flanks of the Alviras rocks, and also, according to some eye-witnesses, from the sea itself. This smoke lasted several days, and it was all the denser in proportion as the underground noise which accompanied the shocks was loud (see *Philosophical Transactions*, Vol. XLIX., p. 414).

The effects of the Lisbon earthquake were felt upon the same day and at the same hour in the southern provinces of Spain. Two hours after the destruction of Lisbon a wave nearly 60 feet high

burst in upon the town of Cadiz and inundated the ramparts. So great was the violence of the flood that masses of masonry and earth weighing ten tons were torn from their site and carried nearly a quarter of a mile.

The frequent oscillations of the soil brought on giddiness, and a great many of the inhabitants, thrown down by the violence of the shock, were severely injured, while others though not actually injured, felt sick and very uncomfortable. For four-and-twenty hours, the sea was very rough, its waves advancing and receding every quarter of an hour. The earthquake also did great damage at Ayamonte, where the shocks lasted for a quarter of an hour, and destroyed most of the houses. Half an hour later the sea, joining the waters of the Guadiana, invaded the coast, and submerged the neighbouring islands and the town of Ayamonte, this phenomenon occurring several times in less than an hour. The foaming waves which the flood urged onwards also invaded, and almost completely destroyed, the small town of Canale, and when the waters receded the earth opened and emitted torrents which almost completed the work of devastation.

11.

Extent of the earthquake's sphere of action.—Part of Europe is disturbed.—Violent undulation of the Atlantic Ocean.—The island of Madeira.—Agitation of the Caribbean Sea.

I HAVE endeavoured in the preceding pages to show to what enormous distances the earthquake shock may be propagated in the subterranean strata, and I have compared this motion of the soil to the rapid undulations produced by the fall of a heavy body, such as a stone, into the water.

A striking proof of this power of propagation was afforded by the Lisbon earthquake, as it is estimated to have extended over an area equal to an eleventh part of the whole globe, affecting not only nearly all Europe, but part of America and of the African coast. It is certain that the whole Iberian peninsula was affected on the same day and at the same hour. The towns situated along the coast, such as Cadiz and Setubal, were the first to feel the effects, which were also very severe at Gibraltar, and in the neighbourhood of Malaga. The centre of the peninsula also suffered a good deal, Madrid feeling the first shock at exactly the same time as Lisbon. It is true that the clocks marked 10·47 at Madrid, and only 9·35 at Lisbon, a fact which, as Emanuel Kant has pointed out, only strengthens the

evidence as to the simultaneousness, this being the difference of time at the two places.

Pelasson asserts that the shock disturbed the Pyrenees, and that a crevice more than fifteen miles in extent opened near Angoulême, the bottom of which was covered with a sheet of water. In Provence several springs of water became muddy, and were very variable in their supply for some time afterwards.

The effects of the earthquake were still more marked in the east of France. Upon the 1st of Nov. Briegg, in Switzerland, had many of its houses overthrown and others much damaged the shocks lasting, as at Lisbon, until the end of December, while to the north of the town a spring suddenly appeared upon one of the slopes of the Bernese Oberland.

The other parts of the Alps were not so much disturbed, but many of the lakes showed symptoms of agitation. That of Neuchatel overflowed its banks, and the torrents which run into it were very muddy, while the small lake of Murbner close by is said to have fallen twenty feet, and to have remained at this level ever since.

Lake Como was very much agitated, and among the Italian towns Turin and Milan suffered the most. The former was not affected

until the 9th of Nov., whereas on the 1st Milan seemed likely to be laid in ruins. The Italian coasts also suffered, and it is said that Vesuvius, then in a state of eruption, suddenly ceased to roar, and that the column of smoke which was being emitted from it was suddenly drawn back into the interior of the crater.

In Germany the earthquake showed unequivocal signs of spreading. The thermal springs of Töplitz at once lost their natural limpidity, and for nearly a minute they stopped flowing, the rush of water which followed being of much greater volume than usual. The flow of water was so strong that it inundated part of the town. In course of time the water again became limpid, and, it is asserted, that since that date the springs have become more abundant, and have contained more mineral substances than they did before.

Norway and Sweden were also affected by this earthquake, several lakes there being more or less severely agitated; but the most remarkable fact in connection with it was, beyond all doubt, the oscillation of the sea all along the European coast. It occurred a few minutes after the first shock at Lisbon. At half-past ten the waters rose at Leyden a foot above the ordinary level, and at the same time a violent oscillation shook the principal church at Rotterdam. The sea was

moved not only at the mouth of the Elbe below Hamburg, but along the coasts of Denmark, Norway, Mecklenburg, and Pomerania, and even in the Gulf of Finland.

The British Isles were even more disturbed than the northern parts of the Continent, and great loss of life and property occurred upon the coasts of Cornwall, owing to the sudden rise of the waters of the sea eight or ten feet above their usual level. The same phenomenon, though less marked, was observed at other places on the British coast ; and these were not the only effects of the Lisbon earthquake, for in Essex the water was lifted out of the ponds, the Derbyshire miners thought that the galleries were going to fall in, and several lakes in Scotland rose three feet or more.

The earthquake spread to the African coast, and the most prosperous cities of Morocco, such as Tetuan, Tangier, Fez, and Mequinez, were almost entirely destroyed at the same time as Lisbon. Near the capital of Morocco an oasis, containing a population of 10,000, completely disappeared ; and at Mequinez a mountain was cleft open, and gave issue for several days to torrents of reddish water.

The same phenomena were repeated in the Canary Islands, the Azores, and Madeira, the

last-named of which suffered the most, as the sea rose fifteen feet several times, and did great damage.

The agitation of the ocean and the dry land was also very intense in America, where all the volcanic group of the Lesser Antilles was shaken a few hours after the catastrophe of Lisbon. The small island of Stabia, the coasts of which are very steep and rocky, was covered with the waters ; and in Martinique the water reached to the roofs of the houses, while, upon the wave receding, the shore was left dry for more than a mile. Throughout the West Indies, the coasts were inundated, and it was remarked that the sea around Barbadoes was as black as ink. Humboldt attributes this phenomenon to the agitation of the sea-bed, which in these regions contains large quantities of bitumen.

THE EARTHQUAKES IN CALABRIA.

Calabria.—Earthquakes of 1738 and 1693.—The catastrophe of 1783.—The catastrophe of Polistena.—The rock of Scylla and the Prince of Scylla.—Victims buried beneath the ruins.

ITALY does not contain a more beautiful or fertile province than Calabria, the celebrated region which the ancients called *Magna Græcia*, where once flourished Crotona, Tarentum, Sybaris, and so many other prosperous cities. Situated between the volcanoes of Vesuvius and Etna, Calabria has always been much exposed to the destructive influence of earthquakes. In 1738, terrible shocks occurred in 190 different localities; in 1693, a still more violent earthquake shook the whole of Calabria and Sicily, 60 villages and towns being completely destroyed, while in Catania alone 18,000 persons perished, a medal struck in commemoration of the event recording that the total number of deaths was not far short of 100,000.

More terrible still was the shock of February 5th, 1783. The ground was agitated in all directions, swelling like the waves of the ocean. Nothing could withstand such shocks, and not

a building upon the surface remained erect, the beautiful city of Messina, the commercial metropolis of Sicily, being reduced to a heap of ruins. Upon the 4th of March a fresh shock, as violent as the first, completed the work of destruction. The number of persons who perished in Sicily and Calabria during these two earthquakes, is estimated at 80,000 ; 320 of the 365 towns and villages which Calabria contained being destroyed.

The French geologist, Déodat de Dolomieu, who was in Italy at the time, hastened to the scene of the disaster, of which he has left a very interesting account.

The shock of February 5th was felt at half-past twelve, and lasted two minutes. The ground, disturbed in every direction, seemed to be turning round, while there followed several vertical motions and undulations of such force that several persons were very sick. Towns, villages, detached houses, all alike were swept clean away ; the very stones were reduced to powder and the foundations lifted out of the ground. Messina was partially destroyed by the earthquake, and what remained of the town was devoured by the flames. Not a stone remained standing of the small town of Rosarno ; and a curious phenomenon was observed in the neighbourhood,

circular holes being formed in the plain, of about the breadth of a carriage-wheel. These cavities, very much like shallow wells, were in some cases full of water to within sixteen or twenty feet of their surface; but they were more generally full of dry sand. Afterwards, when excavations were made around these cavities, it was remarked that they were shaped like a funnel, the upper part widening out terminated in a channel, through which the water had sprung up. The town of Polistena was literally razed to the ground, nearly all the inhabitants disappearing beneath the ruins. "I had seen Messina and Reggio," says Dolomieu, "and I had lamented over the fate of these two towns, in which I had not found a single house that was habitable; but at all events the skeleton of these towns still remained. I had seen Tropea and Nicotera, and I could conceive nothing more deplorable. But when, standing upon a height, I saw the ruins of Polistena, the first town in the plain which I had come to; when I contemplated the piles of stones, which are devoid of all form, and cannot even give an idea of what the town was like; when I saw that literally nothing had escaped destruction, I experienced a sensation of terror, and pity, which half paralyzed my faculties."

Numerous and deep fissures yawned out in the ground after the first shock, and remained open



INHABITANTS OF REGGIO AMONG THE RUINS.

after the earthquake was over. Several crevices were also seen at Jerocarno, of a very curious kind, as they extended in all directions, just like the cracks in a pane of glass.



The population of Polistena, Calabria, flying from an Earthquake.

Casalnovato was completely destroyed, and Terranova, which overhung three deep gorges, was precipitated a depth of 325 feet, this unfortunate town being literally turned upside down, 1,400 of its inhabitants being carried down into the abyss.

The village of Moluquello, situated opposite Terranova, and upon the same level, on a plat-

form hedged in by two streams, which flowed in the two valleys, experienced a very similar fate. Part of this village fell into the valley on the right, and the other part into the valley on the left, so all that remained of the site upon which Moluquello stood, was a ridge so narrow that one could not keep one's balance in walking along it.

Santa Cristina, built upon a sandy hill, was hurled down into the valley, and large blocks, detached from the famous rock of Scylla, crushed as they fell several of the houses situated upon the shore of the Messina Straits.

Immediately after the shock of February 4th the Prince of Scylla had taken refuge upon a boat and had advised part of the population to follow his example. At midnight, a fresh shock brought down a cliff, and the sea lashed to fury, rose twenty feet, swept the shore, and broke up all the sailing craft, some of which were carried a long distance inland. The Prince of Scylla perished with 1430 Calabrians. A few shocks were still felt later in the month and during March, but none of them were so violent as the first.

Scenes too horrible for the imagination occurred during this catastrophe, Dolomieu says : " As egotism and the instinct of self-preservation crushed all other feeling, no help was brought to the unhappy victims buried alive beneath the

ruins; yet many of them might have been rescued. When calm was restored, the lower orders, succumbing to the vilest passions of nature, thought of nothing but pillage."

Men might have been seen scouring the fallen ruins, braving imminent danger, and treading under foot dying persons who appealed piteously for help, in order to go and plunder the houses of the wealthy. They robbed the very injured, who would have paid them handsomely for rescuing them. At Polistena, a person of quality had been buried head downwards beneath the ruins of his house, and when his servant saw what had happened, he actually stole the silver buckles off his shoes while his legs were in the air and made off with them. The unfortunate gentleman managed, however, to rescue himself from his perilous position. For several days cries of anguish were heard coming from underground.

At Terranova, four monks were buried in the vestry, where they had taken refuge, only one of their companions managing to escape, and for four days their cries for help were heard without its being possible to do anything to relieve them.

Dolomieu says: "I have talked with a great number of persons who have been rescued from the ruins in the different towns which I have visited, and they all told me that they were under

the impression that only their own houses had been destroyed, and that they could not believe the work of destruction to be so general, nor conceive why there was so much delay in coming to their assistance. A woman at Cinque Frondi was rescued alive after seven days, and many others remained three, four, and five days in the ruins. I have conversed with them, and in answer to my enquiry as to what they suffered most from, the universal reply was : thirst."

Count Bylands de Palstercamp remarks that among the other interesting observations made in regard to this catastrophe was the great difference to be seen in the appearance of the corpses of the two sexes after they had been extricated from the *débris*. The faces of the men all bore marks of their violent struggles and of the despair which had overtaken them at the last ; while the features of the women were not in the least contorted, but told of the most complete resignation. Mothers had their children clasped to their breasts, being apparently intent upon saving them or protecting them from injury ; while other women, crouching in the courtyards, had evidently met death without a struggle. Upon the other hand, it was observed here, as it has been everywhere, that men, and still more animals, deprived of air, can remain for a long time—for ten or eleven days—

without taking the slightest nourishment, and yet preserve all their intellectual faculties. Among several instances quoted by Hamilton is that of two girls of 14 and 16 who were rescued after having been eleven days interred in a tomb formed of ruined walls and roofs. The eldest was holding in her arms an infant six months old which had lived for six days in their prison. The younger had suffered a great deal from the cramped position which she had to remain all the time, but neither complained of having suffered from hunger or thirst. A nun, eighty years old, was the only victim exhumed alive from the convent of Polistena, and though she had been imprisoned nine days, she was in excellent health.

THE ISCHIA CATASTROPHE.

1.

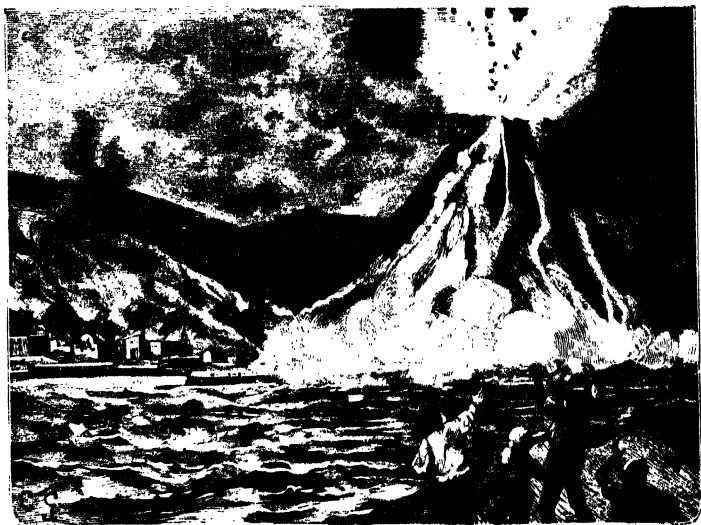
The Island of Ischia.—Mount Epomeo.—Greek colonies.—Eruption of Mount Epomeo.—Ancient disasters.—The shocks of 1883.—The catastrophe of 1884.—Incidents at the theatre of Casamicciola and the Picciola Sentinella hotel.—Child saving its mother.—Acts of heroism.—The Bishop of Caserta.—Girls rescued after remaining underground several days.—Hallucinations of other persons rescued.—The King of Italy's visit. — The cause of the disaster.—Future catastrophes.

THE island of Ischia, which Virgil and Horace call Imarina, rises verdant and fertile between the Bay of Naples and of Gaëta, about seven and a half miles from Cape Misenum. Close to it is the beautiful little island of Procida.

Ischia, the population of which is 25,000, and the coasts of which are very steep, is eighteen miles in circumference, and it belongs to the volcanic district of Naples, which embraces from N.E. to S.W. Vesuvius, the Phlegræan Fields, Procida, and the island of Ischia. The subterranean fire, which now is only emitted by Vesuvius, formerly found its way to the surface through twenty-seven orifices disseminated over the Phlegræan Fields and the neighbouring islands.

The highest point of the island of Ischia is

Mount Epomeo, a volcano which has been dormant for several centuries, and which rises to an altitude of 2,772 feet above the level of the sea, and which has upon its slopes twelve large



Eruption of Mount Epomeo in 1302.

volcanic cones, which, though now silent, are so many witnesses to its former fury. It was under Mount Epomeo, according to Greek mythology, that the gods of Olympus buried the giant Typhœus, whose groans were supposed by the Greeks established in the island of Ischia, to be the underground mutterings which they heard around the mountain. From the summit of

Epomeo, crowned by the hermitage of San Nicolas, the view is one of the finest in the world. The eye embraces the coasts of the Gulfs of Naples and Baiæ, and the shores of Cumæ, Mondragone, and Gaëta, while in the dim distance are seen the crests of the Abruzzi. Around the volcano are scattered the principal towns and villages in the island, viz., Ischia, the capital, with 6,500 inhabitants, Casamicciola, with 3,700, Florio, Lacco, Pansa, Morofano, Serrava, Fontana, Barano, Testaccio, etc.

The earliest eruptions of which history makes mention are those of the years 284 and 305 B.C., after which the volcano seems to have remained at rest for sixteen centuries. But in 1302 it awoke again, and vomited forth enormous torrents of lava, which, after having flowed for a distance of two-and-a-half miles, were precipitated into the sea. Severe shocks of earthquake accompanied this eruption, which lasted two months, and was very fatal to life and property. Since this period, that is to say for nearly six centuries, Mount Epomeo has been inactive ; but its fire is not extinguished, and every now and then it seems as if there was about to be a fresh outbreak.

The first Greek colonists which settled in the island were obliged to abandon it, so frequent were the earthquakes, which overthrew their

temples and their towns, and kept the population in a constant state of alarm. But the island of Ischia is so beautiful and so attractive, that fresh colonies soon took the place of those which had migrated to Cumæ. In short, Ischia, which so many poets have celebrated, is one of the most charming and seductive spots in Europe. The dormant volcano, which formerly lit up the whole island with its fires, and which now, during its sleep, and, like a man dreaming, occasionally shakes it violently, gives a wonderful activity to vegetation. There is a profusion of vines, rose, lemon, orange-trees, mulberry trees, cotton-plants, myrtles, and laurel. Milk, herbs, and fruit are all of the best quality. The whole country is one vast garden spread out at the foot and along the slopes of the giant which warms it, and makes Ischia more fertile than any other island in the Mediterranean. The underground fire also imparts special value to the thermal springs, and raises their temperature to 178 degrees Fahrenheit. The sky of Ischia is nearly always blue, and the air as pure in summer as in winter. All this makes the island a delightful place of sojourn, and there is not a spa in Europe where the time passes more agreeably.

Since the last eruption of Mount Epomeo in 1302, earthquakes have become more and more

rare, though in 1827 a shock destroyed part of Casamicciola and Lacco-Ameno, while again in 1881 and 1883 part of the island was severely shaken.

The earthquake of March 4, 1881, had some very distressing consequences. There were two shocks that day, the first at half-past one, which lasted seven seconds; the second, at two o'clock which lasted only half that time. A third shock even was felt three days afterwards, on Monday the 7th.

A great part of the town of Casamicciola was destroyed, and there were 126 persons killed and 177 injured, while 700 houses fell in. The catastrophe was at first attributed to an eruption of Vesuvius, which took place the day before; but Professors Palmieri, of Naples, and Orazio Sylvestre, of Catania, gave it as their opinion that the shock must have been caused by some local phenomenon, perhaps by the falling in of some underground galleries constantly sapped by the action of the mineral waters, and Palmieri pointed out that a few minutes before the first shock the waters of the thermal springs had been in a state of ebullition.

The shock of July 28, 1883, was far more fatal in its consequences, first, because the season was at its height, and visitors were very numerous;

secondly, because the earthquake, which was in the same direction as the previous one (*viz.*, towards the sea), instead of lasting seven seconds, lasted fifteen, or even thirty according to John Lavis ; and finally because it occurred, not in the day-time, but at 9'30 in the evening.

The island was wrapped in dark clouds, the sea was very much agitated all round the island ; everything seemed to indicate that Ischia was about to collapse into the waters, and a sort of quiver caused the ground to tremble, when a violent shock of earthquake, accompanied by a terrible noise, was felt. The population, in terror, fled from their houses, uttering cries of terror, looking for one another in the dark, and making for the shore as in the last days of Pompeii. There was a general scramble for the fishermen's boats, and a scene of terrible confusion, everyone seeking to save himself.

All parts of the island were disturbed, but while Ischia suffered little, Florio and Lacco-Ameno were almost entirely destroyed. Nowhere, however, was the disaster so terrible as in the charming little town of Casamicciola, situated at the foot of Mount Epomeo, the thermal springs of which are so much frequented. This town, with its rows of elegant villas, completely disappeared, only five houses being left standing ; and as 1,800 visitors

were there, in addition to the 4,000 regular inhabitants, some idea may be formed as to the number of victims.

At Lacco-Ameno not a single building emerged from the mass of rafters and stones which, after the shock, marked the site of this once flourishing little place. Out of the 1,593 inhabitants, it is believed that only five escaped. The ruin was complete, and many houses had disappeared altogether, the supposition being that they were swallowed up in the yawning earth.

The terrestrial shock appears to have traversed the island from west to east, and all the villages and hamlets in its course seem to have suffered, in addition to those already mentioned.

The first shock was felt between 9.30 and 10 at night. Several of the survivors state that the approach of the catastrophe was heralded by a gruff and alarming rolling noise, which suddenly gave place to a most terrific sound like the discharges of a large battery of artillery all of whose guns were firing at once. Immediately afterwards the houses oscillated like a sloop rocked by an angry sea, and, under the influence of the shock, crumbled to pieces. A few of the inhabitants, but only a few, had time to get into the street before the houses fell in, but the great majority were buried beneath the ruins.

For a space of fifteen seconds the surface of the ground was agitated in all directions, and many people were flying in terror towards the shore, when they were struck down and buried beneath the mass of falling *débris*. When the shock was over the only sounds to be heard were the cries of terror and anguish from the injured. Not a single light was left burning, and a dense cloud of dust, which blinded and suffocated the survivors, overhung the scene of the disaster, while the poignancy of the situation was increased by the fact that the houses which had only partially fallen in continued to collapse and make fresh victims. No relief was forthcoming for several hours, as those who had escaped the disaster were in too great a state of terror to be of any service to others, while, when they had regained possession of themselves, the material means of relief were all wanting.

At the time of the catastrophe the small theatre of Casamicciola was full, but owing to the lightness of its construction, most of the audience, though more or less injured, were able to extricate themselves from the *débris* and make their escape when the shock was over. But the panic was a terrible one, and some of the spectators were killed by the fall of beams or suffocated by the violence of the current of outer air. All through the night were heard the cries and groans of the

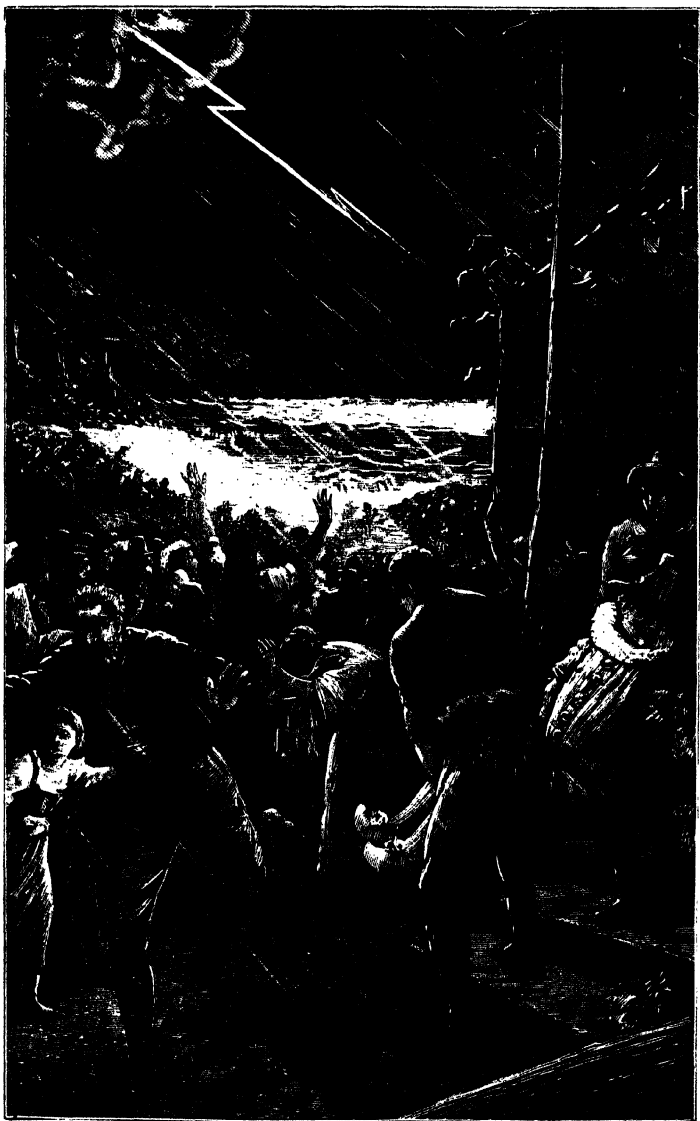
unfortunate victims half buried beneath the ruins ; and these issued not only from the vicinity of the theatre, but from the houses of the square, which had become tombs for their still living inhabitants.

A visitor who was in the theatre at the time of the shock says that he heard a sound like thunder, but it was not until the first oscillations were felt that any symptoms of alarm were shown. "At first," says this eye-witness, "not a cry was uttered, though terror was depicted upon every countenance ; but when the first shock was followed by several others, a shriek of despair went up from every lip. The lights went out, pieces of timber were falling all about us, and the cries of terror were succeeded by shrieks of pain from those who had been injured. It was indeed a trying moment. When the shocks ceased, I crawled, like many others, out of the ruined building in order to reach the shore. The dust was literally blinding. Several times I stumbled over heaps of masonry and rubbish from which heart-rending groans and shrieks were proceeding. Upon the shore, I encountered many others as frightened as I was, and endeavouring to escape in fear of there being more shocks. Seeing that all remained quiet, we retraced our steps in order to relieve the injured. But it was not until the

morning, upon the arrival of the authorities and of the troops sent from Naples, that it was possible to take any effective steps for surmounting the difficulties by which we were surrounded. The firemen, assisted by volunteers, then set to work energetically to clear away the rubbish, laying the dead bodies in a row and handing over the injured to the doctors. It was necessary, however, to go to work very carefully, so as not to injure those who were still unhurt ; and so the work proceeded very slowly, during which time we felt our heart-strings torn by the piteous appeals for relief. Some people were covered by so much *débris* that it took hours to reach them, and when we did so, some of them had succumbed to their injuries, while others had gone out of their minds. The dense cloud of dust had choked many of those who had not been killed on the spot. 'The troops arrived later in the morning, and I then returned to Naples.' Commander Enrico Boltini, professor of surgery in the University of Pavia, had a marvellous escape. The professor, who was a widower, had gone for a holiday to Ischia with his child and its governess, and he had arranged to start the day before the catastrophe, but having met one of his friends in the island, he determined to stay a few days more.

On Friday evening, his child, as they passed the theatre, asked to be taken in ; the professor said that he could not do so that evening, but would the next day. The father and child were seated in the theatre, and it so happened that the title of the piece being played was "An Earthquake." Therefore, when Pulchinello exclaimed in terror, "Un terremoto! un terremoto! Alla mare! alla mare!" (An earthquake! an earthquake! To the sea! to the sea!) the spectators thought at first that this was part of the comedy. They were soon undeceived, as the petroleum lamps were upset and all was darkness. At this critical juncture, the professor had the *sangfroid* to take note of the hour (9.32) and to sit perfectly still, clasping the child in his arms, though all the people in the theatre were seeking to escape.

The shock had been accompanied by an appalling roar like the discharge of several big guns at the same time, and it was followed by a profound silence and a storm of dust raised by the falling buildings. Large crevices appeared, one of them at the place where Professor Boltini was crouching. Soon after he heard in the distance groans, followed by the sound of footsteps, this being probably the marching of the carbineers from Ischia. Owing to his ignorance of the locality and the darkness, he was obliged to remain where



THE POPULATION OF CASAMICCIOLA TAKING TO FLIGHT. ACTOR FATALLY
INJURED, IN HIS COSTUME AS "PULCHINELLO."

he was till daybreak, and when he prepared to make a move he was thunderstruck. He could not see a sign of the square which he had crossed the evening before on his way to the theatre. There was a mass of ruins, and that was all. The first squads of relief from Naples arrived rather before 6 A.M.

Out of the twenty-seven persons with whom he had dined at the hotel the evening before, he could not find one. The actor who had played the part of Pulchinello and given the alarm, was taken to Naples, badly injured, in the dress which he had worn upon the stage.

Another survivor, Signor Giovanni Casini of Arezzo, who also was at the theatre when the catastrophe occurred, gives the following description of the scene :—

“ It was about a quarter after nine when one of my friends suggested that we should go to the theatre. The curtain rose at half-past nine, but we had only heard a few words of the comedy when we felt a terrific shock. I was thrown forward several feet and fell down full length. With this there was a deafening noise, such as might be caused by a heavy train passing over an iron bridge at full speed; during the shock, the ground upheaved and then subsided, like the waves of the sea during a storm.

“ I cannot well describe what followed, for the whole occurrence was like a horrible nightmare. All I remember is that we were a mass of human beings huddled together ; that the petroleum lamps in their fall set fire to the seats ; and that, after trying to extinguish the conflagration, we all rushed violently into the open. I also remember that upon looking up to a tree, I saw that the branches were covered with human beings who had climbed up there.

“ Pieces of wood were piled upon the seashore and set alight as a signal for help. I saw around me a mass of women and old people of both sexes with nothing on but night-dresses, while many of the children were quite naked. Other women, only half dressed, were rushing about like furies with torches in their hands, looking for their children or husband, and imploring others to aid them in their search.”

Nearly all the survivors were stupefied by grief or terror, and few were able to give an intelligible reply to the questions put to them. Among the crowd of fugitives was the engineer, Serafino Tarantini, who said that at the Hotel Sauvet where he was lodging, three rooms had fallen in. He was playing cards at the time, and although the lamps went out he managed to find his way into the garden. The darkness was so intense

that he dared not move till day-break, and then he was a long time making his way to the shore, as there was great danger not only of falling into some crevice, but of stepping upon the unfortunate people buried beneath the ruins. From beneath the ruins extended limbs of human bodies in the convulsions of death, an arm, a leg, or a shoulder sticking out here and there all the way.

He endeavoured to save a few people, but he could not do much, though he did manage to extricate two children. All night long he had heard, amid the lugubrious cries of the whole town, a persistent groaning, and a woman's voice exclaiming: "My children, my children!" At daybreak he saw her standing upon a fragment of the terrace, which had not been carried away, with nothing but her shift on, and still repeating the piteous cry of "My children, my children!" Signor Tarantini says that he was wondering what he could say to her in the way of consolation, when he saw two children playing quietly among the ruins, which might at any moment fall in and crush them, and it so happened that these were hers.

Not less touching, and more tragic in its ending, is another scene described by him. As he proceeded on his way he saw a woman's broken shoulder, and a gloved hand with many rings on

it, emerging from the ruins. This woman was back to back with her husband, who, speaking from the ruins which quite covered him, exclaimed in piteous tones: "Save her, never mind about me." Signor Tarantini, on drawing closer, recognised in her a handsome Egyptian lady who lived opposite his hotel, and he put out his hand to her, and tried to raise the stones which held her prisoner, when a landslip occurred and rendered all his efforts useless.

At the Hotel Picciola Sentinella, where the poet Longfellow resided for some time, an English lady, Miss Robertson, was playing Chopin's Funeral March to several friends, and after the disaster the corpse of this lady and her mother, together with those of eight Swiss, all of one family, were found beneath the ruins. Miss Robertson was found seated in front of the piano with her legs crossed, and might, to all appearance, have been playing still. Death must in her case have been instantaneous. It appears, strangely enough, that the playing of Chopin's Funeral March saved the life of one of the residents at the hotel, as Count Capella, when he heard the march being played, went out, exclaiming: "I cannot stand such music!" He had scarcely crossed the threshold when the building fell in behind him.

When this hotel fell in all the persons living in the rooms at one end of the building perished. Thus Baroness de Riseis, who was in a room in the middle of the hotel, was saved, while the daughter, who was sleeping in a room in one corner, was killed, though her son, who was in a room at the opposite corner, escaped.

The baroness, who was much injured about the chest, spent all the night among the ruins, vainly hoping to rescue her daughter, and would only consent to come away when she recognised that there was no chance of doing so.

One of the most touching acts of heroism was that performed by Adelina Domenichelli, daughter of Dr. Onorato, killed at Casamicciola. This little girl, not twelve years old, after extricating herself from the *débris*, found her way to the spot where she heard her mother groaning, and managed, by the exercise of superhuman courage and energy, to rescue her. She then went to see after her other relatives, and succeeded in extricating her brother, who had an arm broken, and had received other injuries. She sought in vain for her father, and, after having held on for two hours to a fragment of wall which had remained standing, was rescued by some one, who was himself looking for lost relatives.

The dead were first taken to a hut run up in

haste for the purpose, and efforts were made to identify them by washing their faces, but, as a rule, without success. The ruins of the church were then cleared away, and the bodies were deposited there until they could be removed to Naples.

Naples itself had scarcely felt the shock, and when the news of what had happened at Ischia arrived there, the consternation was general, for many families had near relatives staying in the island. Numerous detachments of soldiers and firemen were at once sent off, for all the gendarmes of Casamicciola had been killed.

As the wounded were rescued, they were sent off to Naples, which for several days had the most lugubrious aspect, as one met at every turn stretchers upon which the injured were being carried to the hospitals. Hundreds of people repaired to them and to the mortuary to see if they could identify relatives, and, failing to do so, went over to the scene of the disaster. During the morning following it, a boat arrived containing the bodies of twenty-four young children, some not yet weaned, and all wrapped in white shrouds. They were laid out in a row at one of the hospitals, and the sight was a very affecting one. These, as may be imagined, were crowded, and many churches, transformed into hospitals, were

also full, while the huts run up to receive the dead were insufficient to receive them all.

The Archbishop of Naples upon the morrow of the catastrophe, celebrated a service for the dead, and mass was said for the living, the feeling of consternation spreading to all Italy, notably to Rome, as many families from there were staying in Ischia.

Casamicciola was so utterly destroyed that the syndic of the town did not exaggerate when he assured the Minister of Public Works that nothing remained of it, save the name ; but terrible as the consequences were, they would have been still more so if it had occurred an hour or two later, when everyone had gone to bed. Even as it was, only one house remained intact.

For days afterwards groans were heard issuing from the ruins, and upon the 1st of August, that is to say, after a lapse of nearly a week, people were extricated still alive. The devotion shown by the soldiers was above all praise, and yet it was in many cases impossible for them to extricate those whose groans they heard. Many of them perished in the attempt, but this did not deter their comrades from continuing their work of mercy. The Archbishop of Naples and his clergy were most active in their sympathy ; and the archbishop, who went over to the island to ad-

minister to the dying, placed most of the churches in his diocese at the disposal of the municipality. At Casamicciola, Lacco-Ameno, and Florio, ladies of the highest rank nursed the injured, while ministers and great officers of state worked with the Bersaglieri among the ruins.

A soldier of the 11th regiment of artillery was positive that he heard groans from under some ruins, and, after seven hours' hard work, he came upon a woman's hand. An old woman came up to him as he was holding the hand, and, looking at it and the place itself, exclaimed: "Why, this must be my daughter." They worked on with ardour, and at last got out the whole of the body. But one of the girl's feet was caught in her dress, which was itself held down between two large blocks of stone, so that the dress had to be taken off, before she could be released.

Another soldier, Corporal Curci, of the 6th regiment of Bersaglieri, worked for six hours, head downwards, in a hole which he had dug, being only drawn up now and then to bring the blood down from the head to the feet. At last he called out to his comrades to pull him up, and with him he brought a handsome young girl, who was so overjoyed that she flung herself upon her rescuer's neck and kissed him.

The Bishop of Caserta, Monsignor Mennella,

remained underground twenty-four hours, and one of his relatives heard him calling out : " Release me, I am down here." The men got to work, and, as they dug, the bishop exclaimed : " No, this way," and " try in this direction," but all efforts were vain, and the bishop could not be got at. His voice gradually grew feebler, and at last was silent.

Signora Pontecorvo of Rome had her three children buried beneath the ruins of the Villa Majo, and she was so distracted that she said to the doctor who had come to see her : " They will be cold, poor little things ! Who will feed them ? Save them, and I will give you my soul ! "

Two young ladies named Cobuzio and Löwe were rescued from the ruins by Captain Mastelloni ; and the former gave the following account of her sensations :—" I remained in a faint for some time, and when I came to I heard my companion calling me. We took heart, and waited quietly where we were. The ruins of three storeys above us formed an arch supported only by the post of a bedstead. After hours and hours of waiting we heard the sound of people coming, and called out, but we could not make ourselves audible. Still we heard the motion of spades and pickaxes, but this gradually died away too, and we lost all hope. My companion, who kept

turning about in our prison, found an apple and a prune, which we shared." The two girls had remained in this terrible position for three days, but they had lost all idea of time, for they thought they had only been there ten hours.

Scenes as striking occurred when other victims were released, and some of them were the prey of painful hallucinations. A captain of infantry, carrying a number of articles which he had just seized upon a band of thieves, met two soldiers hurrying to the Piazza Mario, where an old woman was calling for help. This old woman had heard two people talking to each other under the ruins. One of them said, "Gently, gently, I feel that the ground around us is being excavated;" while the other said, "I cannot move; if I do the stones will crush me." After some hard work, an excavation was made, and a young man of twenty appeared. Instead of thanking his rescuers, he began to blaspheme and to exclaim, "Assassins, assassins! I am a tailor, and I shall find some work." He had been subsisting on tomatoes, and when asked if he had had anything to drink, he said, "Yes, vinegar!" His clothes were in tatters, and the captain gave him a priest's robe, which was one of the articles he had taken from the thieves. After further excavations his companion in captivity, a young canteen man, was also released,

and as his clothes were in tatters, he was also arrayed in the garb of a priest. They had been entombed nearly five days. A little further, nearer to the sea, the soldiers released a father and son, each of whom believed the other to have perished, and who were half distraught with joy.

Among the rescues which were little short of miraculous was that of a young man named Francesco Pisani and his cousin, who had been buried for five days beneath the ruins of the Piazza di Majo, the centre of Casamicciola. Francesco was the first of the two released, in presence of the Minister of Public Works, and amid the applause of the soldiers of the 15th regiment of artillery, who, attracted by his cries, had succeeded in saving him. But the rescue of his cousin offered still greater difficulties, as the unfortunate youth, half dead of hunger, and in the midst of a pestilential atmosphere, was buried beneath a quantity of rubbish, the left leg and arm being caught between his father's corpse, and a large iron bar, while the right leg and arm and the head were half buried beneath a large beam. The problem was how to extricate him without bringing all this mass of wood, masonry, and iron about his ears. It was only with infinite precautions, and after eight hours of unflinching and

delicate handling that they succeeded, and then they had to saw the beam which lay over his right leg. When the young man was at last free, a very touching scene ensued, the soldiers being with justice prouder of their achievement than of a battle won over the enemy, while he was profuse in his gratitude. The smell which issued from the ruins was so strong, that several of the soldiers had fainted, and were nearly choked while at work.

Upon the 2nd, the King of Italy arrived in Ischia, and could not restrain his tears when he met the survivors, who had all assembled upon the square facing the port. When the king disembarked, a groan of agony went up from the crowd, which pressed forward and tried to embrace his knees. The syndic of Lacco-Ameno, though he had lost his wife and sons in the disaster, came to meet the king, with his scarf of office over his blood-stained garments, and said "Your majesty, my duty before all else!" The king visited the town and also Florio, and the more he saw, the more impressed was he with the magnitude of the disaster. In accordance with the king's wishes, the work of clearance was carried on with increased vigour after he had left; and Signor Genella, the Minister of Public Works, who superintended all the operations, after having

satisfied himself that there were no more living persons beneath the ruins, had intended, it is said, to have the site of Casamicciola covered with a thick layer of lime, as the emanations from the ruins were so deleterious to the public health. This would have converted the town into a large necropolis, and all that was done eventually, was to dig deep graves, and (instead of taking the putrified bodies to the cemetery) to bury them there, filling the graves with lime and disinfectants, in order to prevent the infection of the atmosphere.

• After the earthquake, a committee of enquiry was appointed by the Italian Government to embody the various observations which had been made during the catastrophe. From the report of this commission, it would appear that the earthquake made 3,075 victims, of whom 2,313 were killed and 762 severely injured. Out of the 672 houses at Casamicciola, the only one left intact was the Villa Russo, on the shore, and 537 were entirely destroyed, while 1,784 of the 4,300 inhabitants were killed. Other statistics give the total deaths at 4,000, and the exact truth is never likely to be known.

The Ischia earthquake was a terrible catastrophe, ruining as it did so many flourishing towns and destroying so many lives, but if the

number of victims was so great this was because the shock occurred during the season and when so many of the peasants were in bed or just going to bed. From a scientific point of view, and compared to the severe shocks which disturb vast regions of the planet, the Ischia earthquake was a phenomenon of merely local importance. The whole of the island, small as it is, was not shaken with equal violence, and upon the other side of the gulf, at Naples and even in Procida, the shock was very slight. The scientific commission, composed of Professors Palmieri, Guiscardi, and Ogliario, commissioned to report upon the nature of the phenomenon, confined itself to the statement that there was a vertical shock, followed by an undulatory shock. Professor Palmieri, however, was of opinion that there would not be a fresh eruption of Mount Epomeo, and as nothing unusual was observed, before or after the catastrophe, in the seismographic instruments of Naples and Mount Vesuvius, he was inclined to think that the earthquake was caused by the falling in of underground grottoes near Casamicciola, which had been hollowed out by the dissolving action of the mineral waters. This is quite possible, though no trace of any such collapse is to be seen. But I am rather inclined to believe, with Mr. John Lavis, who has devoted

considerable attention to the subterranean phenomena of this region, that the cause of the disaster, though local, is not what Professor Palmieri believed it to be, but rather the volcanic action of Mount Epomeo. The vibrations of the soil in Ischia appertain, I believe, to the underground motions which precede the eruptions of a volcano. Thus, for instance, the disturbance of the soil around Vesuvius in the year 73 was the forerunner of the great eruption of the year 79 which destroyed Pompeii, and a series of violent shocks preceded by a few years the appearance of the volcano of Monte - Nuovo, near Puzzoli. Fresh earthquakes of a more violent nature may be looked for, then, in Ischia, the intervals between them diminishing until the dormant but not extinguished fires of Mount Epomeo have burst forth again. It is impossible to say precisely when this will be, but I believe, that the epoch is not very far distant.

THE ANDALUSIAN EARTHQUAKES.

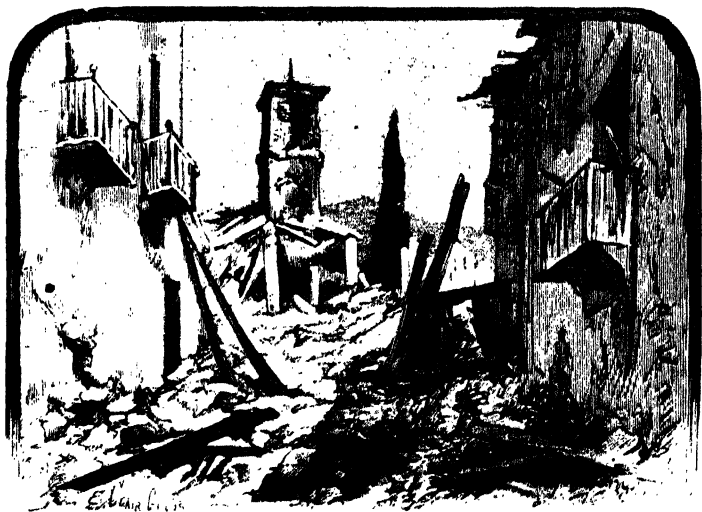
The provinces which suffered.—Earthquake of Dec. 1884.—Panic at Seville.—The Giralda.—The disasters of the town and province of Granada.—Localities affected by it.—The crevice of the Cerro de Gogollos. -- Destruction of Alhama and Abumelas. Voyage of the King of Spain —Cause of the shock.

THERE is no more beautiful country in Europe than the southern provinces of Spain. Their mountains are lofty and picturesque; their fertile plains and valleys are covered with vineyards and orange groves; their ancient and beautiful cities are filled with works of art, and the flags of all nations are seen in their ample and wealthy ports.

These provinces have often felt the deadly effects of the earthquake. At the time of the Lisbon catastrophe, they were much disturbed, and at Cadiz immense damage was done. In 1833, more than 4,000 houses were destroyed in the province of Murcia alone, and twenty-two years later the ground there was in a state of constant tremor for 80 consecutive days (November, 1855, to March, 1856).

About the end of December, 1884, the whole of this region, including the provinces of Andalusia,

Granada, Cordova, Jaen and Murcia, was very severely affected by earthquakes. At the end of November, vibrations of the soil had been felt in Spain, Portugal, Italy, and the south of France. They extended through the valley of the Durance.



Ruins of Abumelas, Spain.

as far as Grenoble, and in the other direction to Toulon, Cannes, and Nice. Often as the trembling of the soil has been the forerunner of a terrible calamity, little heed was paid to them. But on the 25th of December, a month after these first vibrations, the ground rocked violently upon the higher plateaux of Andalusia, in the mountains

of Murcia, and from one end to the other of Granada.

At Seville, the first shock was felt upon Christmas day, at 9·7 P.M. It lasted eight seconds, and was at once followed by a second, less violent perhaps, but of equal duration. The phenomenon was accompanied by an intense underground roar, like that of the hurricane. The panic-stricken inhabitants rushed into the streets, and camped out in them all night. Many houses and public buildings were much cracked, but though the cathedral was shaken to its foundations, it suffered much less than it had done on the 1st of November, 1755, when the famous Giralda, the three-galleried tower of such great beauty, was brought to the ground.

The earthquake was most severe in the mountainous regions of the province, the small towns and villages built in the ravines and upon the mountain slopes being nearly all destroyed.

In the town of Granada, the population was kept in a state of constant alarm by shocks which recurred day and night for three weeks. A great many houses fell, but the Alhambra was not injured. For several nights the inhabitants of Granada bivouacked around large fires lighted in the streets and squares, and when the news of the ruin wrought in the small towns reached



EARTHQUAKE IN THE MOUNTAINS OF ANDALUSIA.

[p.]

Granada, more than 20,000 of the inhabitants fled, and encamped in tents outside the town.

Fifty-six towns and villages were severely damaged, some twenty of these localities being entirely destroyed in less than ten seconds. In the evening of December 25th, after the first shock, 1,320 houses fell in the town of Alhama, and 280 collapsed afterwards, while 576 corpses were taken out of the ruins. The whole town was annihilated, and it is proposed to build a new one some little distance off, as has been done so often by the Spaniards in Central America, notably in the case of Guatemala, the site of which has been changed four times.

Among the localities destroyed by the recent earthquake in the south of Spain is Abumelas, which was one of the most flourishing and picturesque towns in the province, and which lost 517 of its inhabitants, while 463 houses out of 477 were overturned.

For more than a month, incessant shocks were felt throughout Andalusia and Granada, destroying more than 3,000 houses and many thousands of human beings. The effects produced by the earthquake were very curious in some cases. A belt of territory which embraced the village of Guevejar slipped slowly down the mountain side for several days. Deep crevices, similar to those

caused in 1783 by the terrible earthquake in Calabria, opened in the rock near Torax and elsewhere ; in the neighbourhood of Periana several houses disappeared within the bowels of the earth. The largest crevice was that at Guevejar, a village built upon the Cerro de Gogollos, about six miles from Granada ; this crevice is nearly two miles in length, and it has been impossible to determine its depth. The houses which occupied the spot where the ground opened suddenly disappeared ; the church was swallowed up by the yawning gulf, and only the top of its steeple now rises above the surface. In many places the flanks of the mountains have been rent open, and floods of boiling water have spouted out. It is said, too, that the river Gogollos has changed its course, and the general opinion is that there has been an upheaval of the soil in certain parts of the district affected, which has since been visited by great numbers of tourists and geologists. The spectacle was a heart-rending one in the country districts, to which the panic-stricken inhabitants of the towns and villages destroyed had fled. While they were wandering about exposed to cold and hunger, their ruined homes were being disinfected and the corpses of their relatives and friends covered with quicklime.

The lamented young king had a painful duty



THE TOWN OF ALHAMA, AFTER THE DISASTER. SEARCHING AMONG THE RUINS.

to perform when he visited the scene of this dire catastrophe, and it was one of the last acts of his life brought to such a premature end.

There is much uncertainty as to the causes of this particular earthquake. Several hypotheses have been put forward, such, for instance, as the effects of underground caloric and central heat ; while other observers, struck by the way in which the rock, which constitutes the soil of Andalusia, was broken up, attributed it to underground disruptions ; while others, again, ascribed it to the constriction of the soil, owing to the slow but continuous cooling of the earth's surface. My own opinion is, that it was due to the first of these three causes.

All this part of Spain belongs to the volcanic basin of the Mediterranean, which with Vesuvius, Etna, and Stromboli in its midst, has for thirty centuries been agitated by the internal fire which keeps up a focus of subterranean activity--a focus which is revealed by the fiery mountains of Central Asia, which skirts the Caspian Sea, touches the coast of Africa, crosses the Mediterranean, and extends as far as the Azores, where the peak of Teneriffe rears its snowy crest. Thus, whenever the soil trembles at one point of this vast system, the shock has been felt at some other point. During the Lisbon earthquake the

whole volcanic zone was disturbed, and when the earthquake occurred in Spain the bed of the sea was shaken. So at the time of the Andalusian shock, the sea was very much agitated, both in the Mediterranean and the Atlantic, and not far from the Azores several vessels felt a severe shock, accompanied by a loud noise, emerging from the depths of the sea. Fire is ever at work in this immense furnace, as if it were making efforts to break through the thin crust which imprisons it, and which it can shake but cannot break. So apparent is this that during the height of the recent earthquakes the population of Andalusia expected to see a fiery crater open up, and the appearance of a volcano was reported in the Sierra Elora, near Granada. Although the latter fact has not been confirmed, I should not be surprised to see a fresh volcano burst forth in the Iberian peninsula, just as the Monte Nuovo did upon the Neapolitan coast, or the volcano of Jorullo upon the high table-land of Mexico.

THE GROUPING OF EARTHQUAKES.

Volcanic earthquakes and Plutonian earthquakes.—How to distinguish them.

THE many facts set forth show clearly enough that there is more than a vague connection between volcanic fires and subterranean commotions, but I think it would be too much to say that a crisis in the volcanoes is always the cause of earthquakes, or that the latter determine the volcanic eruptions. On the contrary, it would, I think, be right to regard all these facts as the proof that generally, if not always, the two phenomena have a common origin, and are, though in unequal degrees, the manifestations of one common underground force, which is the internal heat of the earth. At the same time, earthquakes often occur also in circumstances which make it doubtful whether they have a common origin with volcanic phenomena. For if we often find volcanoes becoming agitated or suddenly quieting down when the ground begins to quake around them, and even at a great distance, not less frequently do we find earthquakes disturbing whole

regions covered with volcanoes without the action of the latter being at all affected. I have already pointed out that this is the case in the Andes.

The observation of these facts enables us to distinguish two groups of subterranean vibrations ; first, a group of volcanic earthquakes, so called because they are produced entirely by the fire of volcanoes ; secondly, a group of Plutonian earthquakes which are not closely connected with the action of burning craters.

The first group comprises not only the trepidations of the soil in the immediate vicinity of the volcanoes, but all the commotions which occur in volcanic regions, and which may reasonably be attached to the action of the volcanic fires even when these shocks occur some distance from them.

The second group, therefore, comprises the shocks, the centre or starting-point of which is at a great distance from any active volcano. It is true that even in this case the vibration of the soil might be considered as an effect of the subterranean caloric, and that so the whole group of Plutonian earthquakes might be connected, though indirectly, with the volcanic phenomena.

This was how these phenomena were regarded even twenty years ago in the world of science ; for, with the exception of Darwin, Sir Charles

Lyell, Boussingault, and a few of their followers, all the earthquakes were attributed to the action of the central fire, which was also regarded as the cause of the volcanic phenomena. And even in the present day, many independent, skilful, and



Fall of Rocks in the Interior of the Earth.

sagacious observers, after having carefully weighed the pros and cons, hold that earthquakes are produced, if not by the central fire, the existence of which is an hypothesis, at all events by the underground heat, which undoubtedly does exist, and the action of which is powerfully displayed upon the surface of the globe.

II.

A third group of earthquakes.—Fall of subterranean caverns.—
Action of springs.—Settling down of mountains.

NEVERTHELESS, when the centre of disturbance is in a region where one sees neither active volcanoes, nor extinct craters, nor volcanic rocks, nor traces of subterranean fire, one naturally is led to enquire whether the cause of the phenomenon is not more local and nearer to the surface than internal fire would be. It is thus that after numerous and patient researches, there are many people inclined to admit not only the existence of the two groups of earthquakes already mentioned, but to add a third category. Independently of the volcanoes, these shocks would be caused, not by the underground heat or the gases and fluids which it dilates, but by certain mechanical motions of the globe, such as the falling-in of caverns, the settling of mountains, the slipping away of rocky strata, and the rupture of equilibrium far down in the soil. It is argued that anything which can rise to such changes may also provoke vibrations upon the surface. This is how the earthquake when due to this mechanical process is explained. When a rocky stratum in the interior of the earth overlaid by another stratum suddenly gives in, this sudden rupture of equilibrium produces in the

mineral mass a movement which is transmitted athwart the strata above and terminates in a shock upon the surface of the earth.

According to this theory, a grotto falling in under the eroding action of the subterranean waters, a landslip in the interior of the earth, a mere crinkling of the earth taking place at the base of a mountain in consequence of the gradual cooling of the terrestrial crust, would suffice to produce upon the surface the violent shocks and vibrations, which will last as long as the disturbed rocks have not completely settled down and recovered their equilibrium.

The earthquake in the Canton of Valais, Switzerland, in 1855, was one of those which many men of science attribute to a sudden rupture of equilibrium in the bed of subterranean rocks. In their opinion this great commotion of the soil was due solely to the subsidence of the lofty mountains which overlook the valley of Viège. Like those in the Bernese Alps, the Valais mountains are composed of substances which easily dissolve and dilute in the water which filters through the rocky strata and forms regular subterranean rivers and streams. This water, as we can well believe, after having circulated in the interior of the earth, brings away with it a great quantity of mineral substances when it again forces its way to the surface.

A single one of the many mineral springs of Louèche, at the foot of the Gemmi, in the very centre of the Valais—I mean the St. Laurent spring,—brings up 4,000 tons of gypseous substances ; that is to say, 1,750 cubic yards of matter composing the base or foundation of the mountain. In the course of a century, this spring would in this way excavate a hole or grotto, seven feet high, through a stratum of gypsum more than half a mile square. As there are hundreds of these springs in the Valais which are mining without respite, and from century to century, the foundations of these mountains, it is easy to understand that the unceasing action of the waters has in time worn great holes in the lower depths, and that at last the whole body of the mountain suddenly subsides. It is easy to understand, too, how terrible must be the shock at the moment when this mass—we are dealing with mountains ten thousand feet high—settles down upon its new foundation, and some such underground occurrence as this may well have been the cause of the great Viège earthquake. Otto Volger, the Zurich professor, who followed the phases of the disturbance very closely, said that this was not merely an hypothesis, but an absolute certainty. Other geologists, however, have pointed out that the year 1855 was one specially notable for the number of

earthquakes which occurred during many months in Asia and America as well as in Europe, and that several shocks of the Viège earthquake had coincided, to the very hour, with shocks at Broussa and Constantinople. These geologists concluded, accordingly, that all these shocks, including the Viège earthquake, were due to the same cause, the disturbance in the valley of Viège being produced by subterranean fires, and not by the subsidence of the Alps.

THE VALAIS EARTHQUAKE.

The Valais.—The valley of Viège.—Shock of July 25, 1855.—Destruction of towns and villages in the valleys and on the mountains.—The town of Grechen.—Fall of enormous rocks and blocks of ice.—Avalanche.—Propagation of the shock.—Child crushed to death.

THE Canton of Valais is for the most part shut in by a belt of mountains and glaciers, and, with its verdant fields and shady valleys, it gives one the impression of an island or an oasis, though situated in the heart of the continent of Europe. The icy streams which surround it cause it to resemble an island, while the frozen peaks and desert plateaux which shut it off from the rest of the world, and the everlasting snow which is raised in whirlwinds by the storm, make an oasis of it. Westward, between the Dent-du-Midi and the Dent-de-Morcles, the enormous mountain range which rises to an altitude of ten thousand feet is intersected from top to bottom by a single gap. This narrow, abrupt, sombre gorge, 8,500 feet deep, is the only means by which access can be gained to the Valais. Clusters of small towns, villages, and hamlets cover the country, and they may be seen hidden in the tufts of verdure or

scattered here and there in the valleys, by the banks of the streams, or on the grassy slopes of the mountains.

One of the most picturesque valleys in the canton is that of Viège, at the bottom of which is



Child Crutch

the small town of Viège, or Visp. In 1855, this charming region was visited by an earthquake. The weather had been intolerably hot for several days, and the inhabitants were anxiously awaiting the thunderstorm which would clear the air, when on July 25th at 1 P.M., just as the rain had begun to fall, a terrible and sudden commotion shook the

whole country. This first shock, vertical and very abrupt, accompanied by terrible subterranean detonations, was followed by undulatory motions of the soil. The inhabitants, who at the first shock had rushed out of their houses, were thrown to the ground and rolled about like so many helpless logs of wood. Houses fell in all directions, the wooden chalets all of a piece and breaking into bits when they struck the ground, while the houses built of masonry were brought to the ground on the mountain summits as well as in the valley. The two handsome churches with their lofty steeples were brought down at the first shock, and the whole of the town was laid in ruins.

In the valleys of Viège and St Nicholas nearly all the villages were destroyed, and many other localities, situated upon the slope of the mountains and upon the tablelands, were also affected. The pretty little town of Grechen, upon the mountain summit, close to the snow-line, was completely destroyed. Moreover, the whole range, nearly two miles in height, was so shaken that the mountains were observed to rise and fall, their lofty crests being seen to swing to and fro in the air. The disturbance of these immense mountains was followed by great landslips, villages being crushed by the falling of large fragments of rock,



A VIEW OF THE VALAIS.

while the blocks of ice came away from the large glaciers, and snow fell in avalanches into the valley.

The subterranean detonations, the roar of the thunder and of the falling rocks, and the thunder of the avalanches echoing through the valley, struck terror into the hearts of the population, causing them to believe that the whole range of the Alps was about to fall in. Some idea of the violence of the earthquake may be formed when we remember that the shocks which started from the valley of Viège extended over an area of 176,000 square miles, through the enormous masses of the Alps and the Jura, and were felt in France from Grenoble, Valence and Lyons, to Troyes and Paris; in Germany as far as Wetzlar and Heidelberg; and in Italy as far as Milan, Parma, Turin and Genoa. And strange to say this earthquake, the shocks of which are said to have been as severe as those of Lisbon, which lifted up the highest mountains in Europe and destroyed whole towns and villages, claimed only one victim, this being a boy who was playing at the door of a house in Grechen.

FREQUENCY OF SHOCKS AND THEIR GEOGRAPHICAL DISTRIBUTION.

I.

Earthquakes are more frequent than is generally believed.—Periodicity of some earthquakes.—No country is certain of immunity.

EARTHQUAKES are much less rare than is generally supposed, and the close observer is aware that they are, on the contrary, very frequent. From 1850 to 1857 the total number of shocks recorded was 4,620, spreading over 1,810 days in the northern, and 637 in the southern, hemisphere. Not a day passes without two or three earthquakes being recorded, and as many are either not recorded or occur in uninhabited regions, it may be assumed that several thousand shocks take place in the course of the year. It is probable, in short, that if the terrestrial surface of the whole earth could be observed from day to day it would be found that there is a constant state of agitation at some point or other. If the Island of Ischia had not been inhabited, the slight shocks which occurred there would scarcely have been noticed. Shocks of this kind are perpetually occurring in Asia and America without attracting notice.

What draws so much attention to earthquakes like those of Ischia in 1881, and of Chio in 1880, is not the grandeur of the phenomenon, but the loss of life accompanying it.

There are regions which are nearly always



Traveller accompanied by Indians in the Andes.

agitated by subterranean shocks, while others enjoy immunity for years, and even for centuries.

In the countries subject to the immediate action of the volcanic fires the soil vibrates almost unceasingly, as may be observed upon the western slope of the chain of the Andes in Central and South America. The valley of San Salvador, for

instance, which is overshadowed by one of the great volcanoes of Central America, is subject to such constant disturbance that the inhabitants have given it the name of Conscouttan (hammock). Although the soil trembles, especially in the immediate neighbourhood of the volcanoes, the shocks sometimes occur at a great distance from the latter, and, as I have already pointed out, are occasionally the most violent of all.

Just as in volcanic regions it is believed that their great eruptions occur at regular epochs, so in the countries which suffer from earthquakes it is held that they recur periodically. In Peru, for instance, it is the general opinion that two disastrous earthquakes are to be looked for in a century.

It is curious to note that several of the most violent earthquakes took place there after the lapse of a century. At Lima, for instance, there was a violent earthquake on the 17th of June, 1578, and again upon the same day in the year 1678. In Chili, especially at Copiapo, it was long thought that there was a periodic return of earthquake shocks every twenty-three years, as they occurred in 1773, 1796, and 1819, but this idea was dispelled upon the recurrence of severe shocks at much shorter intervals, notably in 1822 and 1835.

It can, I think, safely be said that no region of

the earth is completely protected against the subterranean action and that there is no country the nature of the soil in which excludes the possibility of a catastrophe. Whether caused by the subterranean fire, or the settling down of the depths of the earth, these shocks occur in the torrid zone as in the polar regions ; in the immediate neighbourhood of volcanoes as at a great distance from them ; upon the lofty summits as well as in the level plain, or in the depths of the ocean.

II.

How people get accustomed to earthquake shocks.—Frequency of the shocks in South America.

IN countries where, as in France, Germany, and England, earthquakes are somewhat rare, it is difficult to form an idea of how frequent they are in the equinoctial region of the New World, the inhabitants of which no more keep account of the number of shocks than Europeans do of the number of showers, and where one is sometimes obliged to dismount from a horse or carriage while the ground is trembling, as Humboldt and Bonpland did once while going through a forest, when the ground shook continuously for a quarter of an hour.

In Quito people never think of leaving their

beds when underground mutterings (*bramidos*), which always seem to proceed from the volcano of Pichincha, announce, sometimes seven or eight minutes in advance, shocks, the force of which is rarely in proportion to the intensity of the noise. The indifference of the inhabitants, who know that their city has not been destroyed for three centuries, soon communicates itself to the foreign visitors. In these countries, upon the western slope of the Andes, upon the coasts of Ecuador, Peru, and New Granada, one gradually becomes as much accustomed to the incessant undulations of the soil, as the sailor does to the motion of the vessel caused by the shock of the waves.

Since the beginning of the century, when Humboldt was studying the earthquakes of equinoctial America, the soil has not ceased to vibrate there, the violent shocks succeeding each other year after year without interruption.

Without going so far back as the earthquakes of Nov. 19, 1822, Nov. 16, 1827, and February 20, 1835, which ruined so many towns and fair provinces, from the tableland of Bogotá to the south of Chili, I may mention some more recent shocks, such as those of 1868 and 1877, which destroyed most of the towns on the Peruvian coast, notably the towns of Iquique and Pabillon. On the 8th of September, 1882, violent shocks were felt in

Venezuela, New Granada, Ecuador, and Peru. Since then there was a series of constant trepidations, though less violent than the first shock in September. After this there was a period of tranquillity lasting several weeks ; but on March 27, 1883, at 9.25 P.M., a long, deep underground muttering was heard at Iquique, the southernmost part of Peru. Soon after an earthquake shock startled the whole town. Two other terrestrial disturbances had occurred on the 7th of March at 11.25 P.M. and at Andes (Chili), as well as in the town of Copiapo at 3 P.M. on the 8th of March. Besides, the volcano of Ometepa, in the lake of Nicaragua, which had been dormant for centuries, burst forth in smoke and flame.

The shock felt at Copiapo on the 8th of March was also felt throughout nearly the whole of Colombia. At Cartagena and Turlio, at the mouth of the Atrato, the shock was violent, but did little damage. At Huda, upon the river Magdalena, the oscillation lasted more than a minute, and in the State of Antioquia much damage was done ; while Medellin, the capital of the state, came off almost scathless, though the cathedral suffered a good deal. In the town of Antioquia, the façade of the cathedral was suddenly thrown forwards in a slanting direction, several pillars were overthrown, and all the houses

suffered more or less. At Garumal the prison and 35 houses were destroyed; at Aquedas the town-hall was destroyed; while at Abejirral the church and several of the houses were severely shaken and partly demolished. At Rinagana, the principal village in the territory of Darien, the huts, made of palm-branches, were overturned, and the rivers rose and fell with alarming rapidity.

At the same time, the Taya Indians, living in the same district, had remarked with alarm the frequency of earthquakes and of the topographical changes which, they said, had completely modified the aspect of the country. They say that dull mutterings were constantly heard in the south-eastern region, which very few whites have explored; and from this we may conclude that there was some volcanic agency at work in the district of Atrato. A large island at the mouth of the river Atrato, which had been hydrographically surveyed by a United States steamer in 1862, disappeared altogether.

The West Indian Islands and the shores of the Gulf of Mexico are also agitated by frequent and severe shocks. It was recorded that the Antilles were agitated in 1797, almost at the same time as the town of Riobamba, situated in the midst of the volcanoes of Ecuador, and was razed to the ground, and that they remained in a state of

disturbance for eight months consecutively, since when scarcely a week has passed without there being a shock in one or other of these islands. Exclusive of slight shocks, there were, according to the *American Journal of Science*, seventy-two severe earthquakes in America during 1882, of which thirty-eight were on the Pacific Coast, from California to the south of Chili, and six in the West Indian Islands.

III.

- Shocks in Switzerland and Italy.—Destruction of the finest monuments in Greece.

IN Europe, earthquake shocks are frequent in Iceland and Italy, around the volcanoes ; and so they are at a considerable distance from them, upon the southern coasts of Spain, in Greece and Switzerland, notably in the Canton of Valais and the Bernese Alps. From the tenth century to the present day, there have been recorded more than 1,600 earthquakes in Switzerland, many of them very violent ones. After that which destroyed the town of Bâle in 1356, the shocks, as I have said, continued for a whole year, and so it was after the Viège earthquake in 1855. Southern Italy and Sicily were disturbed, between

1850 and 1857, by 509 earthquakes in sixteen days, and Central Italy by 196 in 175 days.

According to official statistics, 2,225 houses were destroyed in Italy by earthquakes during



Ruins of a Greek Temple in the Island of Delos.

the year 1870, though there were no very severe shocks in that year.

Greece has suffered more, perhaps, from earthquakes than any other European country. The frequency of these shocks has destroyed the most cherished of her monuments, not only at Corinth, Athens, Thebes, and many other cities, but in the smiling islands of the Mediterranean peopled by

the Greek race. The Colossus of Rhodes, the temples of Cyprus, Milo and Crete, were all reduced to dust by the dread earthquake shock.

IV.

Shocks in Egypt and along the coast of Africa.

It cannot be said what part of the continent of Africa, still so little known, has suffered most from earthquakes, though many are known to have occurred on the northern coast, and along the shores of the Red Sea.

•The monuments of Egypt have suffered much from earthquakes, which are less rare in the valley of the Nile than used to be thought. The Colossus of Memnon, shattered to pieces in the year 27, is an illustration of the damage thus done. In the year 365 a terrible earthquake, which extended throughout the whole of Egypt, destroyed Alexandria, 50,000 people perishing in the ruins or in the waters which invaded the city. A solemn service was held every year upon the anniversary of this fatal occurrence.

V.

Earthquakes in Asia Minor and Syria.—Earthquake which rent the veil of the temple at Jerusalem.—Destruction of the city of Antioch.—Earthquakes in the extreme East.—Regions where shocks are unknown or very rare.

THE earthquakes in Europe and Africa are not frequent or violent, as those in certain regions of Asia. The mountains of Persia, and those of the Caucasus, the basin of the Caspian Sea, Asia Minor and Syria, are often devastated by terrible shocks. The whole of this zone of disturbance appears to be connected with the great volcanic focus of the Thian Chan chain, or Celestial Mountains, in Central Asia, a focus which is constantly displaying its force by furious eruptions.

This zone of underground activity extends from east to west, not only to within a short distance of the Caspian Sea, to Baku, and from there to Asia Minor, but, so far as one can judge, towards Lisbon and the Azores, through the volcanic basin of the Mediterranean. In this vast region earthquakes are most frequent and most violent in Asia Minor and Syria.

We have plenty of proofs that the whole of Asia Minor has constantly suffered much from earthquakes. That which occurred in the seventeenth year of the Christian era destroyed the twelve principal towns of the province. Tiberius

had them rebuilt at his own expense, and they in return presented him with a magnificent pedestal, which he had placed in the forum of Puzuoli.

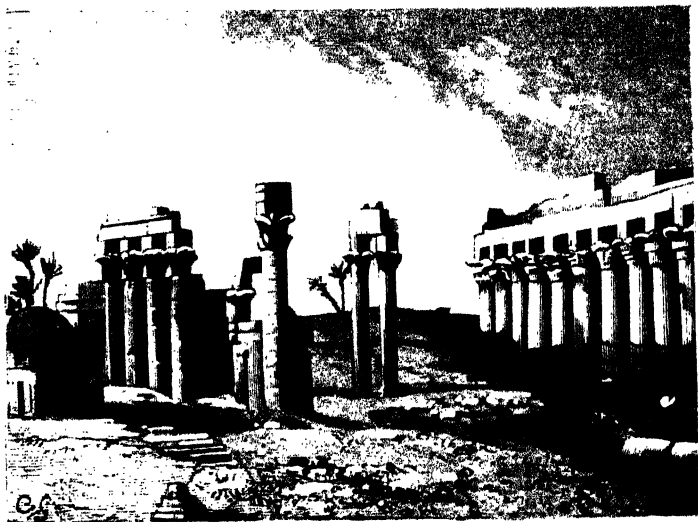
In the year 33, upon the day of our Lord's Crucifixion, occurred the earthquake which rent the veil of the temple in twain, and completely destroyed the town of Nicea, in Bithynia. The shock was felt throughout all Asia Minor, and it extended upon the other side of the Mediterranean to Greece, Sicily, and the Italian mainland. There is a large rock which overhangs the shore at Gaëta, and, according to tradition, the enormous fissure which runs through this rock from top to bottom was caused by the shock which occurred in Palestine, and until within a very recent period it was the custom for vessels to salute the rock as they passed it, in commemoration of the solemn event.

During the reign of the Emperors Valens and Valentinianus, upon July 22, 365, a terrible earthquake shook the vast territory of the Roman Empire, especially Asia Minor and Syria. The waters of the Mediterranean receded suddenly from the shore, but returning in fury immediately afterwards, they inundated all the coast, while the shores of Asia Minor were ravaged by earthquake shocks as well. This catastrophe caused great consternation, coming as it did so soon after

the severe shocks which had destroyed the towns of Palestine. In all the provinces of the empire men talked of the wondrous prodigies which had accompanied the disaster, sent, as many believed, by God to punish those who, in the East as in the West, had given ear to heretic doctrines. This, they said, was why only the priests and holy men of the Church could appease the Divine wrath; and if the town of Epidaurus had escaped the ruin which befell all the other towns along the coast, it was because the inhabitants had taken the statue of St. Hilary to the sea-shore. The saint made the sign of the cross, and the mountain of water, bending low before him, forthwith receded. Few towns have suffered more than Antioch, the sumptuous capital of Syria. It sustained its first disaster in the year 115 A.D., while the Emperor Trajan was in the town. In September, 458, it was laid in ruins, more than 80,000 people being supposed to have perished; and it had scarcely been raised from its ruins when, in the year 525, during the reign of the Emperor Justinian, it was again entirely destroyed. Gibbon, the historian, estimates the number of victims upon this occasion at a quarter of a million, most of whom had come to assist at the great festival of the Ascension.

In 1169, and again in 1202, a great number of

shocks destroyed Beyrout, Sidon, and other towns, and upheaved from one end to the other the valleys of the Lebanon. After a long series of further catastrophes came the earthquake of 1759,



Monuments Destroyed by Earthquake at Antioch.

one of the most terrible on record. The shocks lasted 45 days ; but the first, which was the most violent of all, destroyed in a few seconds Antioch once more. The towns of Baalbec, Sidon, St. Jean d'Acre, Foussa, Nazareth, Safit, Tripoli, and many other places were also destroyed. More terrible still was the earthquake of 1822, which, in the fatal night of August 13th, and in the space

of about ten or twelve seconds, killed 30,000 people, and overthrew countless towns and villages. Aleppo, Antioch, Djollib, Riha, Gisser, Chugra, Deiskrich, Armenas, were transformed into heaps of ruins, and in the whole pashalik of Aleppo, there was not a village or hut left standing. Upon the 28th of July and the 11th of April, 1855, two terrible earthquakes destroyed the town of Broussa and many other places in Asia Minor. There were places in the town of Broussa where the houses were not only overthrown, but crushed and triturated to such a degree that a thick layer of lime was all that remained.

In April, 1881, Asia Minor was once more violently disturbed, and the island of Chio, separated from the mainland by a narrow arm of the sea, was severely damaged, the town being entirely destroyed. Upon the 15th October, 1883, Smyrna and all the coast, in the strait of Chio, were again disturbed, the houses of Tchesmé, upon the coast, being much injured, while the town of Lasetala was entirely destroyed.

Further east in Asia, the archipelago of the Indian Ocean has suffered very severely, the earthquakes in the islands of the Sound of Malacca, the Philippines and Japan being most destructive. This is why the houses in Japan are mostly con-

structed of wood and bamboo, and are only one storey high.

These are the regions of the globe in which earthquakes are frequent, while in Germany, England, France, a large part of North America, upon the eastern slope of the Andes, in Brazil, the Argentine Confederation, the centre of China, and Australia they have hitherto been of rare occurrence. But for all that it would be going too far to say that they are assured of immunity, for in 1861, the eastern slope of the Andes, where no earthquake had ever been known to take place, was violently disturbed, the town of Mendoza being the scene of the catastrophe described in the following chapter.

THE CATASTROPHE OF MENDOZA.

The town of Mendoza before the catastrophe.—The disaster of 1861.—Incidents.—Rescues due to the intelligence and fidelity of dogs.—A French traveller had foreseen and predicted the catastrophe.—Recent warning.—Disquieting symptoms in the volcanic region around the town.

SINCE the conquest of Peru by the Spaniards, no violent earthquakes had been remarked in the valleys and plains of the eastern slope of the Cordilleras, though every now and then some very slight shocks had been felt at a few isolated parts, in the immense plain which extends at the foot of the Andes, from Chili to Buenos Ayres. The flourishing cities of this region believed therefore that they were safe from the subterranean scourge which had wrought so much mischief on the other slope. This was especially the case with Mendoza, from which town, situated at the foot of the Andes, upon the road which leads from Valparaiso to Buenos Ayres, may be seen the cone of the volcano of Tupungato, the crest of Mount Maïpau, and the great fiery mountain of Aconcagua, whose summits, covered with eternal snow, rise to a height of more than 19,000 feet. It might have been thought that the view of

these mighty volcanoes would have prevented the people of Mendoza from being lulled into security ; but they had been accustomed from their infancy to regard them as harmless, and never dreamed of their ever bringing destruction upon their fair city.

Mendoza had about 20,000 inhabitants and 1500 houses, nearly all of them very handsome. It also contained two very large hospitals, several schools, a splendid cathedral, and several churches. Its trade was prosperous, and more than a hundred large shops testified to the extent of its commerce. There was no such library in the whole of the Argentine Republic, its theatre was most sumptuous, and the Alameda, its public promenade, was regarded as the finest in South America.

One evening, an immense red and blue meteor slowly traversed the sky from east to west, and the volcano of Aconcagua broke into an eruption upon the night following, 20th March, 1861, without any premonitory sound or sign ; the earth quaked violently, and in less than a minute the town of Mendoza had disappeared. It was transformed into a vast field of ruins, the highest of which were not more than three feet above the ground. Never, within the memory of man, remarks M. Ernest Charton, has a town been so taken by surprise, for in this case the earthquake

was not preceded by the underground mutterings which, even if only a few seconds in advance of the shock, give some sort of warning. Upon that night, and in less than four seconds, 15,000 people were buried beneath the ruins. Horrible noises, cries of terror, the heart-rending howls of men and animals filled the air, and a thick cloud of dust darkened the sky.

The central shock probably proceeded from the volcano of Aconcagua, and it extended over a vast area. The town of San Juan, situated a hundred miles to the north of Mendoza, was levelled to the ground at the same moment, and more than 3,000 people perished. Three hundred and fifty miles further on, the houses of Cordova were overthrown, and even Buenos Ayres felt the effects of the subterranean shock.

As is always the case upon these occasions, there were many touching episodes. M. Charton, for instance, relates in the 33rd volume of his *Magasin Pittoresque* that during the disaster a Frenchman named Tesser, an hotel-keeper who had settled with his family at Mendoza, was buried beneath the ruins. One of his intimate friends was wandering among the ruins, his eyes dry from having shed so many tears. Coming upon the site of the hotel, he found it impossible to recognise the position of the different rooms,

and he was about to move away when he noticed beneath a mass of splintered beams and charred stones, his friend's dog who was moving. He found that the poor brute, whose hind legs and



Dog Sniffing the Body of his Master.

loins had been badly crushed, was trying, despite his sufferings, to paw up the ground with his forepaws, howling piteously as he did so. Tesser's friend of course guessed that he must be buried beneath the *débris*, and after fetching some persons to aid him, succeeded in extricating the unfortunate man, whose left leg and arm were broken. His mouth and eyes were choked with clay, but

he was still breathing, and after he had drunk a little water, he seemed relieved, his first movement being to stretch out his right hand to the dog, who just managed to drag himself up to his master and then died.

Tesser, when able to speak, asked what had become of his family, and it was, alas ! necessary to tell him that they had all perished ; but he had just strength to pronounce the name of his youngest daughter, and point with his finger to a place apart from that of the rest of his family where he had put her to bed. Some of those who were standing round went to look for her, more to relieve the father's anxiety than with any hope of finding her, but they had the infinite satisfaction of doing so and of bringing her back alive. A beam had fallen athwart her bed and protected her. But she was badly hurt about the head, and was half dead with hunger. Father and daughter were both placed in a tent beneath a tree and there they remained more than two months, their recovery seeming for a long time doubtful.

Eye-witnesses of the disaster have often told me that for a week before it occurred, the possibility of it was generally discussed upon the strength of a prediction to that effect having been made by a French geologist, M. Bravard.

Entrusted with a scientific mission by the

Russian Government, M. Bravard had just returned from a journey in the higher regions of the Andes, and while in the midst of the volcanoes which overlook the Argentine Plains, he had been struck by the great activity of these subterranean forces. He heard the volcanoes roaring furiously and yet not emitting any smoke or fire ; but nearer the valley of Mendoza, at the foot of the volcanoes, he felt the soil tremble very much. He concluded from this that the shocks would increase in violence and spread further into the plain, unless the fluids, gases, and vapours, then imprisoned in the depths of the earth, succeeded in forcing an issue through the mouths of the volcanoes. When he reached Mendoza, he could not help expressing his views to those whom he met, and they excited considerable alarm, as he was known to be a man of great experience.

As he had just been appointed director of the Museum of Parana, then the capital of the Argentine Confederation, he was only going to stay a few days at Mendoza, and upon the evening of March 20th, while playing dominoes at the house of a friend, he could not help alluding to the peril which he had predicted. He was speaking of it even as he stood at the door, wishing his friends good-night, and while he spoke the earthquake came, the house fell in, and he was killed.

The owner of the house where this happened, M. Matussière, was about fifteen miles off Mendoza, in the Cordilleras. He was returning from Valparaiso, the commercial capital of Chili, where he had been to make some purchases. Suddenly, he heard an underground noise, louder and more terrible than thunder, and he felt as it were a presentiment that a great misfortune had befallen him. Still no shock was felt on the mountain and all seemed still in the plain over which the moon shed a flood of light.

Seized with terror and the prey of poignant emotion, he hurried on his way and reached Mendoza to find it in ruins. He long searched in vain for the site of his own house, and was about to give up the task in despair, when he suddenly saw a big dog which belonged to him spring from the ruins and come to greet him. The dog put his paws upon his master's shoulders, and then began barking and turning round, as much as to say "Follow me." M. Matussière did so, and soon found himself upon the site of his house, where several people had already assembled, attracted thither by the dog. Groans were heard from below, and the people set to work to remove the *débris*, the dog all the time leaning down towards the place whence they came and barking loudly. M. Matussière himself aided the workers



RESCUE DUE TO THE INTELLIGENCE OF A DOG.

as much as his distress would allow, and eventually his wife and one of his children were rescued alive. All the others had perished.

The dying and the injured remained without relief all night after the disaster, for the authorities had disappeared, and there was no one to organise assistance, while to add to the horrors of the situation, bands of brigands swooped down upon the city. They completed the destruction which the earthquake had left unfinished, strangling the wounded and chopping off the fingers or wrists of those who had valuable rings or bracelets on them. It was not until the next day that help could be given to the wounded, and these wretches driven off.

The disaster has left an indelible impression upon those who witnessed it, and all those whom I have questioned on the subject, even many years after, could scarcely reply without emotion. When I asked them how this was, they told me that they could not think of the horrible shock without fancying that they felt the soil tremble and saw the earth yawning open at their feet.

The town of Mendoza is now once more one of the most pleasant cities in South America, and though nearly all its former inhabitants emigrated, declaring that they would no longer live in a spot where they had endured such agony, most of

them have returned, attracted by the souvenir of those whom they mourn.

In the new town, the streets are wide and planted with trees, the squares are large and numerous, and the houses of one storey and built of wood. As there had been no earthquake since, people had come to regard the danger as past for good; but there were several shocks there in the spring of 1885, which have destroyed the sense of security once more. An eye-witness relates them as follows:—

“ I had just come in (March 30th, 1885, 10.30) and was, as usual, smoking a pipe before going to bed. I was reading a report of the Academy upon the satellites of Mars, when one of the windows suddenly opened and shut again with a bang. This was the first shock. I thought that a dog had come in at the window, and stooped to look under my desk. The window again flew open, and I was obliged to cling to my desk, my chair coming with me. Not being able to understand it, I jumped sharply up and was at the same time flung to the right. My jaws were, unknown to me, forced so tightly together that I bit through the stem of my pipe, which fell to the ground, the end of the stem remaining in my mouth. At the same moment I felt a pain in the pit of the stomach, just like that caused by sea-sickness.

Then it occurred to me that there was an earthquake, and I at once realized what to do. Snatching up my watch, I loosened the second-hand, noticed the time, and fixed my eyes on the corner of the ceiling opposite to me. Six seconds after, I heard a noise in the distance like that of an engine when it is blowing off steam; then the howling of dogs; then the wind among the plane-trees in the street outside; and at last I saw the corner of the wall slope slowly to the left for a second, and then suddenly return to its place. But it regained its position so quickly that I took fright and ran to the door in order to escape; but the door would not open. The dogs continued to howl, and at last I managed to open the door and get out into the boulevard, where most of the inhabitants had congregated in their night-dresses. The sky was clouded over, and a fine rain began to fall. The dogs howled all night, and most of the inhabitants passed the night in the streets. The underground noise lasted quite another minute. It would seem that the earthquake which destroyed Mendoza 24 years ago, took place in analogous circumstances. Altogether, there were three shocks; had there been a fourth, I think it would have settled Mendoza."

Since then there has been no earthquake, and I daresay that the people of Mendoza have forgotten

all about the alarm they had last year. But the subterranean forces are still in full blast not far from the town, and the upper regions of the Cordilleras are again the theatre of the same phenomena which made such an impression upon M. Bravard previous to the catastrophe of 1861.

THE EARTHQUAKE IN THE ISLAND OF CHIO.

Chio, the pearl of the Greek archipelago. — Patriotism of the inhabitants. — Earthquake in 1883. The capital is destroyed. — Prompt supply of relief. — Fresh shocks.

THE terrible catastrophe which befell the verdant and flowery island of Chio, with its atmosphere embalmed by the perfume of roses and orange-blossom, is still fresh in our memory. Its intelligent and industrious inhabitants, who comprise the most able of Greek traders and merchants, had succeeded by dint of labour in effacing the traces of the devastation wrought by the Turks during the Greek insurrection. Thanks to the active efforts and generosity of the wealthy inhabitants, the capital had been raised to a high pitch of prosperity, and 600 steamers entered the port in the course of a twelvemonth, while it was well provided with hospitals, schools, and libraries. The Chiotes were justly proud of the prosperity of their island, when on April 3, 1881, all this prosperity was annihilated in a few seconds by a violent earthquake, and many thousand people were buried beneath the ruins of the capital.

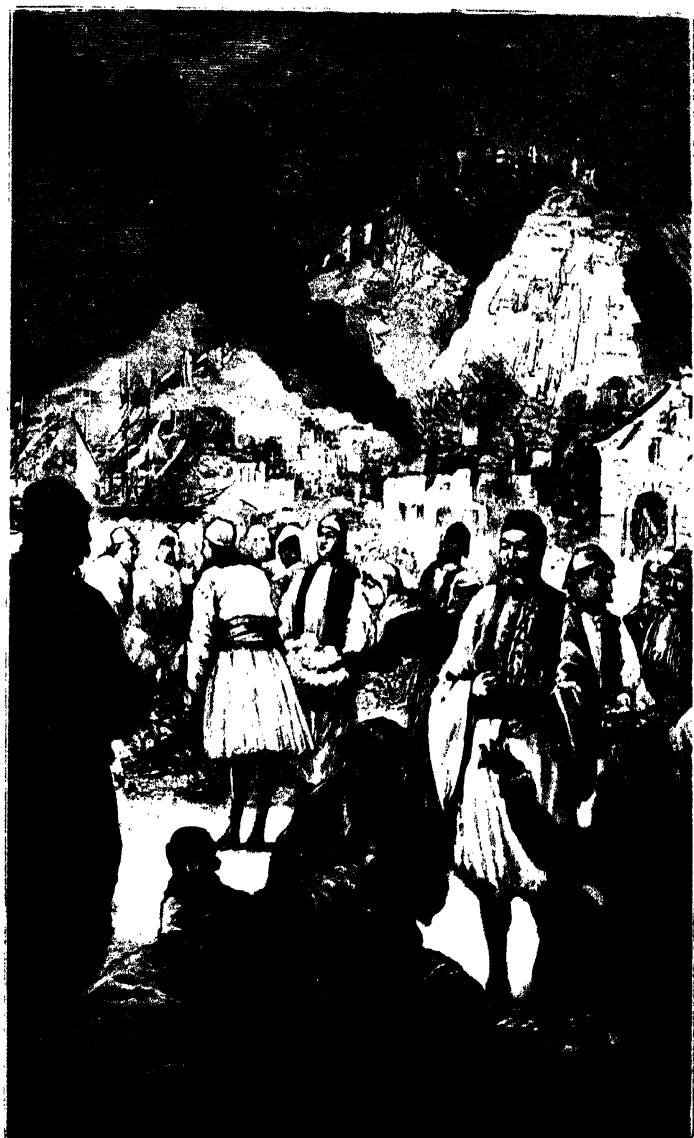
A great many villages were destroyed at the same time, and nearly all the inhabitants were made homeless and destitute. But charity, which is now-a-days very cosmopolitan in its action, soon came to their relief; and although the shock had also been very severe upon the opposite coast of Asia Minor, it was from there that the first boatloads of provisions, tents, and timber were despatched.

More than five thousand persons perished in this catastrophe, and after the search for the victims among the *débris* had been completed at the end of a week, it was found that about ten thousand more had been more or less injured. As it was impossible to clear away all the ruins, the authorities were compelled to be content with pulling down the walls which were still standing; and, to prevent an epidemic, they spread disinfectants over the layer of stone and lime beneath which more than a thousand corpses were still lying.

All the coast of Asia Minor was severely agitated, and there were a hundred people killed in the town of Tchesmé.

The shocks continued for several days, each one being accompanied by a terrific underground noise.

Two years later, on October 15, 1883, the island of Chio was again visited by earthquake



DISTRIBUTION OF RELIEF AFTER THE CHIO EARTHQUAKE.

1944 17

shocks, which, though less severe, caused great alarm, and at the same time the coast of Asia Minor was much disturbed, the town of Smyrna



was a good deal injured, and the houses of Tcheshmé, which had hardly been rebuilt after the earthquake of 1881, were again much damaged, while the town of Latejata was completely destroyed.



EARTHQUAKES AND THE SEASONS OF THE YEAR.

Popular beliefs as to earthquakes and the seasons. — They are confirmed by recent researches. — Seasons during which earthquakes are most frequent. — Number of shocks winter and summer, and also day and night.

ALL those who have made a careful study of nature, from Aristotle, Strabo, and Pliny down to the leading naturalists of the last century, were of opinion that there must be a connecting bond between earthquakes and the climacteric phenomena, notably the different seasons of the year.

But during the first half of this century, geologists and natural philosophers have shown that this connection does not in reality exist. There were very few men of science who were prepared to admit the possibility of this coincidence about twenty years ago. And yet the belief that the frequency or force of earthquakes depends upon the seasons is not only very ancient but very deep-rooted. It prevails among the inhabitants of the western coast of South America, in Italy, the West Indies, Central Asia, Japan, and the Archipelago of the Sound. The inhabitants of Kamschatka, of the Kurile Isles and of Japan, assert that earthquakes are most frequent and severe at the time of the equinoxes. In the equatorial regions of America, where ten months, it may be, elapse without a drop of rain falling, the natives regard repeated earthquake shocks as foretelling rain.

Upon the contrary, the Europeans and natives in the Moluccas live during the rainy season in light huts, as it is universally believed in this region of the globe that earthquakes are caused by heavy rains, and in the Dauphiny Alps they are attributed to avalanches. This is probably because the earthquake shocks there have generally occurred at the beginning of summer, when the snows melt. Thus at Pignerol, in the

valley of Chisone, shocks are felt every year during the spring months.

Throughout Central America, there is an unanimous testimony to the fact of earthquakes being prevalent mainly at the beginning and end of the seasons of drought and rain ; that is to say, towards the end of October and the beginning of November upon the one hand, and towards the end of April and the beginning of May upon the other. They have been remarked to be specially frequent after the heavy rains in the last days of October.

All this shows that in the regions subject to earthquakes the inhabitants believe that they are more or less frequent at certain seasons.

So considerable a body of facts was not to be pooh-poohed, or put upon one side, without careful examination. Minute calculations were therefore made by Hoff and Mérian, and more recently by Professors Alexis Perrey, Otto Volger, and Emil Kluge, and they found that the ancients were evidently right, and that there was solid foundation for the popular belief as to the connection between earthquakes and the cycle of the seasons.

Great was the surprise of the world of *savants* in 1834 when Professor Mérian, of Zurich, having classified the 118 earthquakes which had

occurred at and about Bâle according to their dates, found that there had been many more in winter than in summer.

His conclusions, as might have been expected, were strenuously opposed at first, but fifteen years later they were confirmed by the painstaking and laborious researches of the men whose names are given above.

According to Volger, out of the 1,230 shocks which have occurred in the Alps, 456 have been in spring and summer, and 774 in autumn and winter. The numbers are about the same for spring and autumn, but there are three times as many earthquakes in winter as in summer.

The difference is very marked if the earthquakes are classified by the month, as the following table will show :

January.	February.	March.	April.
150	141	138	119
May.	June.	July.	August.
58	54	40	47
September.	October.	November.	December.
117	111	85	163

It will be gathered from this table that the difference between the earthquakes in winter and summer is enormous, as by comparing the four months of May, June, July, and August, with those of December, January, February, and March, it will be apparent that they are three

times more numerous in the winter than in the summer season.

By studying the problem rather more closely, that is to say, upon a very limited area of disturbance, we arrive at still greater variations between the number of earthquakes in winter and summer. Thus, to give only one instance, Otto Volger found that out of the 98 severe earthquakes which had been recorded up to 1856, 72 had occurred in the winter, and only one in the summer.

In the basin of the Rhine, there have, so far as is known, been 539 severe earthquakes from the ninth century down to 1860, and of these 103 occurred in the spring, 101 in summer, 165 in autumn, and 170 in winter: in other words, there were 335 in the winter half of the year as against 204 in the summer half.

The earthquakes which have occurred in the Lesser Antilles since the beginning of the last century are classified as under:—

	January.	February.	March.
Eighteenth century	3	3	4
Nineteenth century	9	6	10
	April.	May.	June.
Eighteenth century	2	1	2
Nineteenth century	9	9	7
	July.	August.	September.
Eighteenth century	3	4	5
Nineteenth century	4	11	11

	October.	November.	December.
• Eighteenth century	8	3	3
Nineteenth century	9	11	7

This gives a total of 41 earthquakes in the last, and 103 in the first half of the present century, or 144 in all. Out of this total 76 have occurred in the six months of winter, and 68 in the six months of summer.

It also appears from the researches of Volger that earthquakes are less frequent in the daytime than at night. In Switzerland, out of 502 shocks, the exact hour of which is known, 182 occurred during the day, and 320 at night :—

From midnight till 6 A.M.	180
From 6 A.M. to midday	104
From midday to 6 P.M.	81
From 6 P.M. to midnight	140

During the years 1855 and 1856 earthquake shocks were numerous and violent in both hemispheres, and the 472, the exact time of which was known, occurred as under :—

Morning.		Afternoon.	
6 to 7 o'clock,	8 shocks.	12 to 1 o'clock,	16 shocks.
7 to 8 "	8 "	1 to 2 "	10 "
8 to 9 "	24 "	2 to 3 "	18 "
9 to 10 "	11 "	3 to 4 "	18 "
10 to 11 "	13 "	4 to 5 "	14 "
11 to 12 "	17 "	5 to 6 "	15 "
Morning, 6 to	—	Afternoon, 12	—
midday	81 shocks.	to 6	91 shocks.

Shocks in the day from 6 A.M. to 6 P.M. $81 + 91 = 172$ shocks.

Evening.				Night.			
6 to 7	o'clock,	18	shocks.	12 to 1	o'clock,	22	shocks.
7 to 8	"	9	"	1 to 2	"	44	"
8 to 9	"	18	"	2 to 3	"	32	"
9 to 10	"	16	"	3 to 4	"	38	"
10 to 11	"	23	"	4 to 5	"	18	"
11 to 12	"	33	"	5 to 6	"	27	"
Evening, 6 to				Night, 12 to			
12	.	.	.	6 A.M.	.	.	.
119 shocks.				181 shocks.			

Shocks at night, 6 P.M. to 6 A.M., 119 + 181 = 300 shocks.

To the number of night shocks in the years 1855 and 1856 must be added at least 157 others, the exact time of which was not taken, and which have not, therefore, been included in the table, so that, if they were added, we should have a total of 457 shocks at night, and only 172 in the day.

Mr. Squier, the well-known American traveller, during a residence of several years in Nicaragua, Guatemala, and other countries of Central America, remarked that here also the shocks were far more numerous at night than in the daytime. He says,—"It is quite certain that the only shocks I felt were at the periods described, viz., the beginning and the end of the dry and the rainy seasons; and it is also certain that nearly all the shocks occur during the night."

In view of facts so well ascertained, and to which so many more recent observations might be added, it is not possible to doubt that earthquakes present, as regards their frequency, a series of

alternatives, not only for each period of the year, but for each period of the twenty-four hours.

Nor is this in any way astonishing, for if there are regular alternations for the season of the year, especially for winter and summer, the same phenomena might be looked for in regard to day and night; for each day, with its hours of rain and drought, of heat and cold, may be regarded as an embodiment of the whole year. Morning is the spring, noon the summer, evening the autumn, and night the winter, of the diurnal revolution. After having ascertained by numerous observations that the frequency of earthquakes varies with the hours and seasons, one is tempted to conclude with Otto Volger that the prime cause of these phenomena resides, not in the bosom of the earth, but in the general laws which regulate the recurrence of the seasons, the alternations of heat and cold, of light and darkness, of drought and rain, or snow.

THE UNDERGROUND FORCES OF THE ATMOSPHERE.

I. — THE TEMPERATURE.

Brusque changes in the temperature during shocks. — Great decrease in the temperature during earthquakes in Sweden and elsewhere.

THE underground scourge which spreads ruin through Equatorial Africa, the Red Sea coast and the archipelago of the Indian Ocean is also felt, as the reader is aware, in Siberia, Greenland and Iceland.

The earthquake occurs in all regions of the earth, in the torrid as well as in the glacial zones. This is the capital fact, the general law which may be laid down. But the special facts mentioned in the previous chapter prove that in all regions of the globe the subterranean phenomenon is more frequent during the cold season, that is to say, in the winter in high latitudes and during the rainy season in the equatorial region.

That would suffice, apparently, to show that the ambient temperature is not without action upon the subterranean forces, but this is not all. Other facts not less worthy of note tend to show that the earthquake in turn exercises a consider-

able effect upon the temperature ; in other words, that there is between the energy or frequency of the shocks, and the degree of atmospheric heat, a reciprocal action and a connection the nature of which is not fully known to us.



This action is often revealed by sudden variations of temperature during the earthquake. Thus in hot countries, one always experiences a sensation of coolness after a sharp earthquake shock. I do not know of a single exception to this rule, and I may add that the difference is so marked that there is no need of a thermometer to

detect it, though in these countries, as in all others, the thermometer undergoes sudden changes during the shocks.

Then, let us take the earthquake of December, 1856, which upon the same day was felt on the coast of Asia Minor, and in part of Sweden. In the town of Lechsand (Sweden), seven severe shocks were felt at 3 P.M. It was the precise moment at which equally violent shocks were felt at Smyrna, and up to the time the shocks occurred at Lechsand the temperature had been higher for the season of the year than it had ever been known to be. But during the shock, the cold set in quite suddenly, and in a few hours the temperature had varied 86 degrees, the thermometer marking 36 degrees of frost at Lechsand and Upsala after the earthquake.

At the other extremity of the subterranean undulation, the same phenomenon occurred at the same hour, for while the thermometer at Smyrna marked 70 degrees before the shock, two hours later it had dropped to 41 degrees, the night being the coldest of the whole winter.

The thermometer also fell several degrees at Cairo, when the earthquake occurred there on October 12th, 1856. There was a severe earthquake shock in the regions of the Mediterranean on December 29th, 1854, and the weather was

remarkably fine, especially on the French coast. But after the first few shocks, the thermometer fell nearly to freezing point at Nice and Marseilles.

Many analogous instances might be given, but the only one I will add is, that of the earthquake at Kiachta in Siberia, where the thermometer marked 27 degrees of frost on the 27th of December, 1856. When the earthquake occurred, the cold became more intense, and in half an hour it was 25 degrees below zero.



II.—THE PRESSURE OF THE ATMOSPHERE.

Observation made during the Calabrian earthquake. — Sudden drop of the barometer at the time of an earthquake. — How Humboldt accounts for this. Great atmospheric wave produced by the Java earthquake. Seismometer or seismographs, instruments indicating the motions of the soil. — M. d'Abbadie's seismometer. The seismometer and the microphone. — Microseisms, or very slight trepidations of the ground. Their analogy with severe shocks.

THE subterranean disturbances being most frequent during winter, the autumn equinox and the night, we are led to the conclusion that there is a connection between these commotions and the pressure of the atmosphere, for it is in the winter,

at the time of the equinoxes and at night that the atmospheric pressure varies the most, and that the oscillations of the barometer are in consequence the most marked.

At the time of the Calabrian earthquake in 1785, it was remarked as peculiar that, despite the fineness of the weather, the barometer was down to tempest. This fact, added to similar ones observed at the time of the Lisbon earthquake, had already attracted the notice of men of science, who thus were led to conclude that there must be some connection between the subterranean phenomenon and the phenomena of the atmosphere.

Although neither Humboldt in South America, nor Ehrmann in Central Asia, could discover any relation between the atmospheric pressure and the subterranean disturbances, more recent facts go to prove that this relation does exist. Thus during the great earthquake at Chili (February 20th, 1835), Caldeleugh noticed that the barometer fell just before each shock.

After the terrible shock of July 25th, 1855, in the valley of Viège, the soil, as I have said, was in a state of vibration for a month. Now, Otto Volger ascertained that during the whole of this time the shocks occurred at night, at the very hour when the oscillations of the barometer were

most pronounced. Upon December 27th, 1856, the earth shook at the same time in Austria, Asia Minor, France and Peru, and the barometer in Austria had never dropped so much as it did on that day. It is scarcely possible to doubt after all this, that there is a connection, a link between the pressure of the atmosphere and the earthquake. But the question then arises as to what this connection is. Sometimes the atmospheric pressure precedes the earthquake and seems then to be a predisposing cause. How in this case the atmospheric pressure exercises an influence upon the subterranean agents it is impossible to say.

More often still it is the earthquake which precedes the atmospheric pressure, and seems to be the cause of it, and in that case we are equally in the dark as to how the underground shocks act upon the atmosphere: all we can tell is, by a comparison of the facts observed, that there is reciprocal action between the aerial and the subterranean phenomena.

Humboldt was of opinion that the elastic fluids, that is to say the gases and vapours discharged into the atmosphere during an earthquake, might have an effect upon the barometer, if not by their mass, which is small by comparison with the mass of the atmosphere, at least by reason of the fact that at the time of a

severe shock an ascending current is formed which diminishes the pressure of the atmosphere. This, in his opinion, would explain a fact of which there appears to be no doubt and which I have already pointed out, viz., the mysterious influence which, in Central America, earthquakes have upon the climate and the order of the dry and the rainy seasons. Earthquakes in New Granada and Ecuador have often advanced the rainy season, and this phenomenon, which has also been observed in India, is perhaps produced by the perturbation which the shocks occasion in the electric condition of the clouds. But this, after all, is only guess-work.

Just as the great earthquakes produce the vast marine waves of which I have spoken, so they also give rise to immense undulations in the atmosphere above our heads.

It will be remembered that at the time of the earthquake in the Strait of Sunda, between Java and Sumatra, in 1883, the undulations caused by the great shock in the waters of the Indian Ocean and the Atlantic extended to the coasts of Europe, and were felt two days after the earthquake. But the most severe of the shocks, which occurred at 7 A.M. on the 27th of August, at the time when the volcano of Krakatoa was swallowed up by the sea, also gave rise to an atmospheric

disturbance, as attested all over the world by the unusual oscillations of the barometer. Measured by the distance between the two places, the first atmospheric wave must have travelled to Berlin from Java at the rate of 875 miles an hour, and Dr. Forster, of the Berlin Observatory, states that sixteen hours afterwards there was a second and similar disturbance of the barometer, caused no doubt by an atmospheric wave which in this instance came from an opposite direction, viz., America. This wave therefore, must have travelled round the world in thirty-six hours, and as a matter of fact, a fresh barometrical oscillation, though less pronounced, was observed at Berlin thirty-six hours after the first. A third direct wave of disturbance was felt at the end of thirty-seven hours, and it may in short be affirmed that the convulsion in the Strait of Sunda, determined undulatory motions in the air of sufficient force to travel three or four times round the world. How, after this, can we doubt as to there being a connection, a reciprocal action which improved instruments may some day enable us to gauge more in detail between earthquakes and atmospheric agencies. Moreover, the instruments which we now possess, tell us this much : that the subterranean forces and those of the upper air are in constant communication, and that they are

so not only when the severe shocks of earthquake suddenly reveal the reciprocal action of these forces to the most cursory observer.

In the chapter on "Forewarnings" I referred to the ingenious apparatus which have in many cases permitted of the earthquakes which follow volcanic eruptions being announced in advance. These apparatus, to which the name of seismometer has been given, consist as a rule of clocks and moveable hands, which, by their combined motion indicate the direction and even the force of the shocks.

One of the oldest seismometers is a small round basin full of mercury, and placed upon eight small goblets placed at equal distances apart. Over these goblets, round the basin and upon a level with the mercury, are eight orifices with slot-houses leading into the goblet. The apparatus is placed horizontally upon the ground, and in such a direction that the orifices correspond exactly to the eight principal points of the compass, viz., N., N.W., W., S.W., S., S.E., E., N.E. If the ground undulates, the mercury runs out through one of the apertures into one of the goblets, and the quantity of mercury run out, and the position of the orifice, indicate what is the force and the direction of the shocks.

Thanks to the initiative of a group of *savants*,

most of the meteorological stations in Switzerland and Italy are provided with much more delicate seismometers. An apparatus, constructed upon an idea set forth by M. d'Abbadie many years ago, is now used, which is affected by the slightest vibrations of the soil, and which permits of microscopical examinations being made of shocks so slight that they would pass unnoticed but for this instrument. This is why the shocks are called *microseisms*, to distinguish them from the more pronounced shocks which are universally perceptible.

M. d'Abbadie has for the last thirty years been pursuing his seismic investigations at Hendaye, just under the Pyrenees. He has had a cavity shaped like a cone excavated in the rock to a depth of forty-six feet, and in the lower part of this cavity he had placed a quicksilver bath, the surface of which is ruffled by the slightest shock of the ground. Above the quicksilver is placed a lens with a long focus which reflects upon the surface of the ground the movement of the quicksilver, and it is this reflection which is observed by means of the microscope. With this apparatus, the microscopical motions of the terrestrial surface are brought to light just as the oscillations of the atmosphere are made manifest with the barometer.

For the last four or five years, the Italians

have applied the microphone to the examination of earthquakes, and more especially of microseisms. Nothing can be simpler than a microphone, consisting as it does of two pieces of carbon just touching one another and traversed by an electric current passing into a telephone. Such, briefly described, is this wonderful instrument, the sensitiveness of which is beyond description. Amplifying with wonderful intensity the slightest motion or sound which occurs in the air or anywhere near it, it enables one even to hear the noise made by a fly with its legs as it crawls along the floor.

The study of earthquakes by means of such varied and ingenious instruments as this has already yielded some startling results. For instance, it has been discovered that microseisms, much more frequent than severe shocks, are, like the latter, accompanied by subterranean sounds, and that the sounds, transmitted and magnified by the microphone, resemble the loud reports produced by a sharp earthquake. You have, though upon a reduced scale, the same murmurs, the same buzzing, the same thundering and the same hissing, which but for the microphone would not reach the human ear. The passage of a gust of wind is perceived at a distance by the microseisms, so that the atmospheric disturbance is

always accompanied by a subterranean disturbance of equal intensity.

All these microscopic sounds, these perpetual and infinitely slight movements, may be taken as showing that the interior of the earth is the scene of a vast system of meteorology, of which earthquakes represent the storms.

III.—UNDERGROUND STORMS AND AERIAL STORMS.

Earthquakes accompanied by tempests and storms. Cyclones and earthquakes at the mouth of the Ganges and in the West Indies. Fireballs and strange lights during the Cumana earthquake of 1799. - Ozone and the earthquake in Andalusia. - What ozone really is.

At the beginning of this work, I examined the question as to what were the presages of earthquakes, and the result of the inquiry was that neither storms, nor water-spouts, nor tempests, nor the northern lights, nor rain, nor meteors could be regarded as infallible harbingers.

But if most earthquakes occur without being announced by any of these phenomena, it is none the less true that atmospheric disturbances, notably storms and tempests, sometimes precede the shock. In Central America, for instance, as well as in the regions of the Mississippi and the Ohio, an earthquake is nearly always preceded by

a gust of wind or thunderstorm which, as a rule, ceases at the very moment of the shock.

But as a rule, the tempest and the lightning accompany or follow the earthquake much oftener



than they precede it, and when they occur in this way at the same time as the shock, it is hard to say whether the latter is the cause or the effect of the atmospheric disturbance.

A great many facts of ancient and recent occurrence might be adduced as evidence in this respect, but the following will suffice.

Upon the night of October 11 to 12, 1737,

a terrible cyclone was raging at the mouth of the Ganges. Just as the storm subsided, violent shocks of earthquake destroyed a great many houses along the banks of the river, including 200 at Calcutta. The waters of the Ganges rose more than thirty feet above their ordinary level, and it is calculated that more than 300,000 persons perished, victims either of the storm or the earthquake.

The reader may remember that the island of St. Thomas, in the West Indies, was visited by a severe earthquake shock on the 2nd of August, 1837, just as the cyclone which had been raging all day was quieting down. In 1855, this island was again visited by a violent shock which was simultaneous with a storm which raged all over the Lesser Antilles. The same thing occurred again in this island during the storm of October, 1867, though this time the shock was a slight one. But three weeks later, on the 19th of November, occurred the earthquake which has been described above, and which was the most severe ever felt in the island.

At the time of the great earthquake of August 21st, 1856, the weather was magnificent all along the coast of Algeria; at Bougie the sea was as calm as a lake and the sky an azure blue, but after the first shock, a sudden gust of wind passed



CYCLONE AND EARTHQUAKE AT THE MOUTH OF THE GANGES. [p.]

with violence over the town, while flames of fire seemed to shoot up out of the sides of the mountain.

The Cumana earthquake of November 4, 1799, was preceded, accompanied, and followed by extraordinary atmospheric phenomena. A reddish light had been seen in the sky during the whole of the previous night, and a strong gust of wind, followed by a thunderstorm, followed instantaneously this first subterranean shock, which, with an upward direction, created great terror among the population. After this first shock the red light was again seen for several nights, and each day at the same hour there were shocks as violent as that which occurred on the first day. Finally, upon the seventh night, a countless number of meteors and bolids shot through the sky, and after this night the mysterious light disappeared, and there were no more shocks.

The dreadful shock in the valley of Viège in 1855 occurred simultaneously with the most severe thunderstorm ever felt in the Valois. And, coming down to more recent times, severe thunderstorms accompanied the earthquake shocks in Andalusia, especially at Granada, which was the centre of the disturbance, while an immense quantity of ozone found its way into the atmosphere.

Ozone is a most singular substance, of which we know neither the origin, nor the physical properties, though it is generally considered to be a transformation of oxygen effected by means of electrical effluvia, while recent researches of a very ingenious kind have taught us that in colour it is azure blue like the sky. Although the sudden appearance of ozone during earthquakes had often been reported, the fact was regarded by men of science as improbable, but there could be no mistake about it this time, as the shocks had scarcely ceased in Andalusia when its presence was noticed all over the scene of the catastrophe. The director of the observatory at the monastery of Uclès, upon the tableland of New Castile, two hundred miles away from Granada, said that he had never seen such a prodigious quantity of this gas in the air.

But we cannot tell whether these floods of ozone were produced in Andalusia by the action of the lightning flashes, and thence wafted to New Castile, or whether the region of Uclès was within the circumference of a centre of electricity, which manifested itself at Granada by luminous effluvia, and above Uclès by invisible discharges producing the ozone.

The outcome of a good deal of investigation leads us to believe that ozone, when found in

large quantities in the air, has an unfavourable influence upon health. So that it may be that the ozone, formed at the time of the shocks and permeating the air, is the principal cause of the indefinable sensation of discomfort and the nervous troubles which are often felt during an earthquake, even by people living a great distance off. Thus the shock in the valley of Viège in 1855 was felt in Besançon, for during the whole day the population of that town and of the neighbourhood was suffering from headache, and other symptoms of fever and discomfort, while many women were prematurely confined.

These meteors, tempests, and violent storms too often accompany earthquakes for us to question the fact of there being a sympathetic connection between them. Sometimes it is the aerial disturbance which seems to provoke the vibration of the soil, but more often the converse is the case.

IV.—ELECTRICITY IN THE ATMOSPHERE AND
MAGNETIC STORMS.

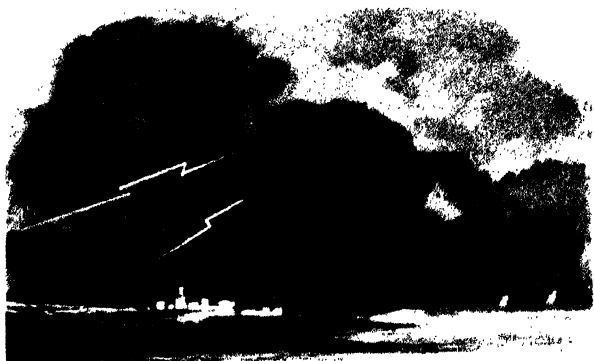
Influence of shocks upon the electric state of the atmosphere.—
Action of shocks upon the electric needle.—Red lights
frequently observed at the time of severe earthquakes.—
Nature of this light.—Magnetic storm following close upon
earthquake shocks.

THE storm which we often see breaking at the same time as the earthquake shock, the storm with its flashes and thunderings is electricity itself, or, to be more precise, it is the greatest electrical phenomenon in existence.

It is certain that the severe shocks of earthquake produce a perturbation of the electric condition of the atmosphere, even when not followed by any storm or flashes of lightning.

Humboldt observed that at the time of the violent shocks, which occurred at the same hour daily from November 4 to 10, 1799, at Cumana, the electrometer was affected, and since then analogous facts have been signalled from all parts of the world in such numbers that we have quite an *embarras du choix*. I will merely cite the case of the earthquake in Mercia, which lasted from November 11, 1855, to January, 1856, the needle of the electrometer being in a state of agitation the whole time, and only becoming steady on January 5, 1856, after the last shock.

- As most readers are aware, electrical and magnetic phenomena are so closely connected that they may be regarded as manifestations of one and the same force. Electricity leads up to magnetism, and the phenomena attributed to the



latter may easily be converted into electrical phenomena in the presence or in the imagination of the observer. It is not, therefore, surprising, when we know that electricity plays a part in the great subterranean disturbances, to know that these latter exercise a potent influence upon the magnetic needle.

During the great earthquake in Chili (1835), the magnetic current was interrupted all along the coast, and at the time of the earthquake in the Mediterranean islands on October 12, 1856, the

commander of the Turkish frigate stationed off Canea, in Crete, remarked that the needle of his compass had deviated from its place a few moments before the first shock, and only regained its position after the earthquake was over. The same fact was noted upon other vessels in these waters, and the magnetic needle of a vessel twenty-three miles off Crete turned eight times upon its axis.

It is also worthy of remark, that during this earthquake which extended as far as the Dalmatian coast and Austria all the electric needles in the Central Meteorological Institute of Vienna underwent brusque and marked deviations.

The Venezuela earthquake of November 4, 1799, had a very perceptible effect upon the magnetic phenomena of the earth. At Cumana the action of the underground shock upon the magnetic needle was very marked and abiding. Alexander von Humboldt remarked, soon after his arrival there, that the inclination of the magnetic needle was 43 degrees, 65 minutes; and on the 1st of November three days before the shock, he carefully verified this by means of the large Bordes compass, he having examined this apparatus at the approach of an eclipse of the sun which he was anxious to follow. Having recommenced the same series of observations upon the 7th of

November, three days after the earthquake shocks, he was much surprised to find that the inclination was less by 90 minutes. Humboldt thought that the needle would return to its former point, but he was mistaken in this, for upon returning to Cumana, after more than a year's absence, he found that it was still where he left it.

We naturally wonder what the reddish light can be which often accompanies earthquakes in South America, uncertain as to whether it is a mist, a vapour, a meteoric cloud of dust, or a cloud reflecting some diffuse light shining in space. But this phosphorescent veil, or cloud, is often seen also in the Strait of Sunda at the time of subterranean convulsions, and it has also been noticed occasionally during earthquakes in Syria and the Mediterranean. This was notably the case at the time of the earthquake which occurred upon the coasts and islands of the Mediterranean on October 12th, 1856, and in a report published at Candia, I find the following passage :—"According to the evidence of sailors in vessels off Crete—evidence confirmed by the inhabitants of that island—a light extended over a great part of the sky before and during the earthquake. It looked like a phosphorescent veil, and this veil, light red in colour, had a sort of quick internal motion so that the whole of it seemed to vibrate

and quiver in the sky. This strange meteor did not at all resemble lightning, and the rays which shot through it could not be mistaken for flashes. The aërial phenomenon disappeared simultaneously with the last shock of earthquake." This curious meteor seems, by its extent, its transparency, its scintillation and the mobility of its light, to have appertained to the phenomena of electricity and terrestrial magnetism, among which the aurora borealis is the most magnificent.

The apparition of the northern lights is generally preceded by great magnetic disturbance. Before and after their appearance, the magnetic needle is all of a tremble, jumping up and down, and turning upon its axis. The perturbations of the compass precede the appearance of the aurora borealis by several hours, sometimes by a whole day. Since the creation of the electric telegraph, these disturbances have had the most singular consequences, currents of electricity running along the wires, interrupting the transmission of messages, and causing the telegraph to ring owing to the abnormal action of the terrestrial magnetism. The equilibrium between the vital forces of the planet which have been disturbed is to a great extent re-established by these storms, which, instead of being confined to a limited district like ordinary thunderstorms, extend to the

whole surface and perhaps also the very depths of the earth. These magnetic storms so often accompany a shock of earthquake that many men of science have held that the celestial meteor and the subterranean meteor must be the effects of one and the same cause.

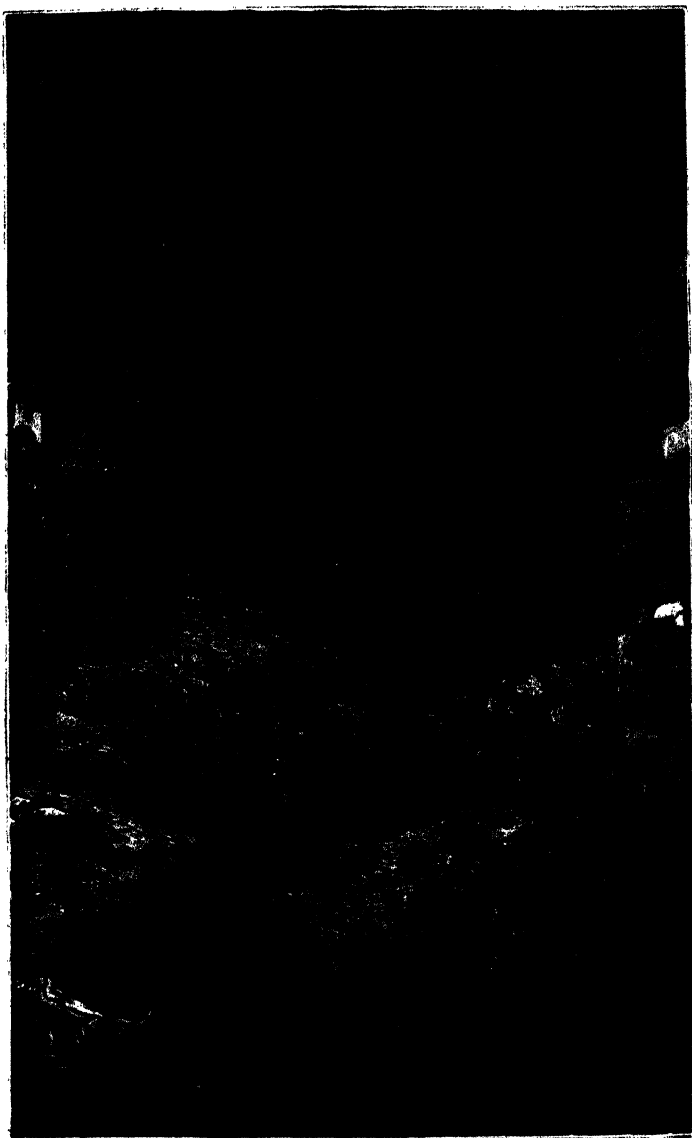


Portrait of Alexander

EARTHQUAKES AT CUMANA.

Alexander von Humboldt at Cumana. — Destruction of the town in 1766. — The shocks of 1799. — Aspect of the sun. — Electric state of the atmosphere. — Action upon the compass. — Extraordinary phenomena. — Thunderstorm. — Bolids. — Strange light in the sky. Impression produced upon Humboldt and Bonpland. — Panic of the inhabitants.

As there are no records at Cumana, and as its archives contain no documents more than 200 years old, we have no precise data as to the earlier earthquakes than that of the year 1766, which was both a very fatal one for the inhabitants and a very remarkable one in the physical history of the country. Humboldt, in the story of his



CHINESE FLYING FROM AN EARTHQUAKE.

travels in the equinoctial regions of the New World, gives some very interesting information with regard to these phenomena.

A drought similar to that often experienced in the Cape Verde Islands had lasted for fifteen months, when on October 21, 1766, the town of Cumana was entirely destroyed, the event being still commemorated by a religious service and procession. All the houses fell in in less than a minute, and the shocks lasted for fourteen months at intervals of an hour or so, while in several parts of Venezuela, the earth opened and vomited forth sulphureous waters.

*Tradition has it that in the earthquake of 1766, as in that of 1794, the shocks were simply horizontal, and that it was only on December 14, 1797 that the movement was an upward one. Upon that day four-fifths of the town were entirely destroyed, and the shock, accompanied by a very loud underground noise, resembled, as at Riobamba, the explosion of a very deep mine. Fortunately the most violent shock was preceded by a slight undulatory movement, so that part of the inhabitants had time to escape.

During the years 1766 and 1767 the inhabitants of Cumana encamped in the streets, and they began to rebuild their houses when the shocks only occurred at intervals of a month.

As was the case in Ecuador after the great earthquake of February 4, 1797, the atmosphere seemed to be resolved into water, and so much rain fell that the year was a very fertile one, while the Indians, whose frail huts are scarcely affected by the most severe shocks, celebrated, in accordance with the ancient superstitions of their race, by feasting and dancing the destruction of the world and its coming regeneration.

The earthquake of November 4, 1799, was also followed by very remarkable atmospheric phenomena. For several days, reddish vapours had appeared at the same hour of the night and covered in a few minutes, as with a thick veil, the azure vault of heaven. This phenomenon was all the more singular because it often happens that there is not a cloud or streak to be seen in the sky for months at a time.

In the night of November 3 to 4 the reddish mist was thicker than it had been at all, and the heat seemed most oppressive, though the thermometer did not reach 77 degrees. The breeze, which generally freshens about nine in the evening, was not perceptible, and the atmosphere seemed to be on fire, the dusty earth breaking up in crevices in all directions.

At about two in the afternoon of the 4th, large black clouds hung over the lofty mountains of

Brigantin and Tataraqual, extending gradually to the zenith. About four o'clock thunder was heard at a great height, but it did not roll as it usually does ; the sound emitted being short and snapping. At the moment of the loudest electric explosion, at 4.15, there were two earthquake shocks, following each other at intervals of fifteen seconds.

The people in the streets cried out with fear, while Bonpland, the celebrated botanist, who was seated at a table examining plants, was thrown down, and Humboldt, though resting in a hammock, felt the shock quite distinctly. Persons who were drawing water from a well 25 feet deep heard a great noise, like the explosion of a heavy charge of gunpowder. The noise seemed to come from the bottom of the well, this being a common phenomenon in most of the countries in America which are subject to earthquakes.

A few minutes before the first shock there was a violent gust of wind, followed by a fall of thunder-rain with very large drops. Humboldt at once tested the electricity of the atmosphere with the Volta electrometer, and the electricity passed several times from the positive to the negative, as happens during thunderstorms, and even, in the north of Europe, during snowstorms. The sky remained cloudy, and the gust of wind

was followed by a dead calm which lasted the whole night.

The sunset was a most magnificent one. The thick veil of clouds suddenly parted near the horizon, and the sun appeared at an altitude of twelve degrees, in a sky of indigo blue. Its disc was enormously magnified and distorted, and wavy towards its edge. The clouds were golden in hue, and masses of divergent rays, which reflected the most beautiful colours of the rainbow, extended as far as the middle of the sky. There was a great gathering of people upon the public square, as the collective phenomena of the earthquake, the thunder which accompanied it, and the reddish light which had been visible for several days, had a great effect upon them, the general belief being that it was the effect of the recent eclipse.

Towards nine in the evening there was a third shock, accompanied by a loud underground noise. All the evening the barometer had been lower than usual, and was at the lowest point just when the earthquake occurred.

It was scarcely twenty-two months since the town of Cumana had been totally destroyed by an earthquake. The inhabitants regarded the vapours which mounted in the horizon, and the absence of a breeze at night as infallible prognos-

ties of a disaster. The uneasiness was very great and very general when on the 5th of November, exactly at the same hour as the previous day, there was a violent gust of wind accompanied by thunder and a few drops of rain. The wind and the storm occurred for five or six days at the same time almost to a minute.

The earthquake of November 4 exercised, as we have already said, a marked and permanent influence upon the electric needle. A few days before the shocks, Humboldt, previous to watching an eclipse of the sun, had carefully verified the inclination of the needle, and he found that on the 7th of November, three days after the shock, it had been considerably reduced.

The night of November 11 to 12 was fresh and beautiful. After about 2.30 in the morning luminous meteors of great brilliancy were seen in the east. Bonpland, the friend and travelling companion of Humboldt, had just got up to enjoy the cool air upon the balcony of the house, and as soon as he saw them he called up his friend. Thousands of bolids and shooting stars were seen in the sky for four hours, and nearly all the inhabitants were witnesses of the phenomenon, as at this time of the year most people get up at four to assist at early mass. The sight of the meteors created considerable

terror, as the older inhabitants remembered that the earthquake of 1766 had been preceded by a very similar phenomenon. Upon the 12th of November the reddish light was seen for the last time, and after that nothing further was seen or heard on earth or sky.

This earthquake made a deep impression upon Humboldt, for it was the first he had been present at, and it was accompanied by very extraordinary meteorological variations. "I could not have thought," he afterwards wrote, "that I should have in time become as familiar with the brusque movements of the soil as we are in Europe with the sound of thunder."

EARTHQUAKES AND THE HEAVENLY BODIES.

The sun and the earth. - Solar spots. - Herschel's hypothesis. - The spectroscope.—The sun is a fiery body. Photosphere, chromosphere, and corona. - Cyclone and storm in the sun. - Volcanic eruptions in the sun. - Observations of Father Secchi, Trouvelot, and Janssen.—The solar spots and the clusters of asteroids. Immense discharge of solar electricity. - Connection between these solar phenomena, magnetic storms and earthquakes.—Influence of the heavenly bodies upon the destiny of the earth.—Action of the planets, the moon, and the sun upon the subterranean forces. The cycle of Saros.—Astronomical time-table of earthquakes and of the dangerous period. Observations and researches of Alexis Perrey, Falbe, and Delauney. The moon and the subterranean forces. - Ocean tides and subterranean tides.

From the earliest times the mind of man has been perplexed by the question as to whether the stars exercise a real influence upon the earth and its inhabitants.

The action of the sun is as visible and manifest as its own light, and thus it is that many people, struck by this vast and beneficent influence, have worshipped that luminary as a god. In these later times it has been suggested that the sun, which transforms the waters of the ocean into vapours, and thus generates the dew, the rain, the springs, the rivers, and organic matter, may extend its influence to the depths of our planet.

Strange events are ever occurring upon the surface of the sun, and bright lights and dark spots are constantly coming and going here. A round spot is first seen like a small black speck, which gradually extends until it becomes larger than the whole surface of the earth. The spots last for perhaps a fortnight, three weeks, or even for several months at a time. But while they last they undergo perpetual changes, first increasing in size and then breaking up into several small spots. There are alternative periods during which the spots in the sun are more or less numerous, and these form regular cycles of about eleven years.

The great astronomer Herschel attributed the formation of solar spots to phenomena similar to the impetuous movements of our atmosphere over the surfaces of the earth where cyclones and tornadoes prevail. He held that the solid and non-luminous surface of the sun is enveloped in three atmospheres, and that the sun, like the earth, has its mountains and valleys. The upper stratum of the triple atmosphere, forced down towards the nucleus of the sun by stormy currents, would thus displace the two other atmospheric strata, each breach in which would cause the opaque surface of the luminary to look like so many spots.

. Although this ingenious theory is in close harmony with the facts which have been observed, it has failed to hold water since the spectroscope, a delicate instrument affected by the slightest traces of incandescent matter, has



The Arctic sky, after a drawing of the twelfth century.

been used for examining the sun. This marvellous instrument has, in the hands of the astronomer, become a probe, which he is able to use for sounding the luminous depths of the sky, and which tells him the nature of the celestial objects thus explored.

If it is possible to ascertain the nature of a planet,

one can also tell what its chemical composition is, and this, thanks to the discoveries of Kirchhoff and Bunsen, without having ever held the fragment of a star in one's hand and subjected it to the methods of analysis. The chemical nature of any luminous body can be discovered by examining through a prism of glass the light which it produces. It is well known that in passing through the prism a ray of light is divided into a coloured fascia which is called the luminous spectrum. This spectrum varies according to the substances which produce it. Sometimes it is quite homogeneous, while at others it is streaked by obscure lines more or less thin, and more or less numerous, while it is also characterized by the presence of rays of very bright and various colours. It is by these peculiarities, invariably found in one kind of light, that men of science are enabled to detect with certainty the presence or the absence of any given substance in a flame the rays of which traverse the prism. The spectroscope it is which enables us to observe in detail these dark streaks and coloured rays. When we find in the spectrum streaks which do not correspond with any known substance, we naturally conclude that we have detected the existence of some new body. Thus it is that one can affirm the existence of a new substance without having seen or handled it.

The infallible signal of this is a weak and uncertain light, vacillating like a shadow.

It is all the same whether the luminous body thus analysed be a few inches off the prism, or millions of miles away, except that in the latter case there is some little material difficulty to be got over in concentrating the light and rendering the spectrum of the remote body visible.

This method of investigation has already produced the most striking results, for it has enabled chemists to discover many simple bodies, the rarity and diffusion of which in rock or in water had hitherto concealed them from the search of analysts, while upon the other hand it has enabled astronomers to undertake a direct examination of the physical nature of the stars.

Thanks to the spectroscope, we have ascertained that the terrestrial substances, the gases, the metals and other foreign matters in our planet are, in the sun, in an incandescent state, and that the body of that luminary is not opaque, as was formerly supposed. The sun is a glowing planet, within which all is movement, light and heat, just as all is wonderful and magnificent. To our eyes it appears like a completely round disc, and its dazzling surface, as seen through an ordinary telescope, is white as snow (see *Le Soleil*, by M. Faye, of the French Institute). But a more

powerful instrument shows that this snow is composed of a mass of small flakes of incandescent matter, of small round clouds bathed in a fluid of not less dazzling whiteness—an igneous fluid composed of hydrogen, oxygen, and all the chemical elements of the sun; a burning sea ever lashed by the tempest, ever agitated by currents of fiery gases; an ocean of fire in which prevails a heat beyond the powers of description, in which flakes and clouds of metallic vapours float and eddy just as the clouds of vapour or water and the snow-flakes do in our atmosphere. This burning and stormy sea, this vast fire, this focus of all light and all heat is the photosphere; the body and nucleus of the sun. Around the photosphere reigns an incandescent stratum of rose-tinted hydrogen, and this atmosphere, 4,500 miles thick, is called the chromosphere. Over this extends the corona, which is an immense crown, a splendid aureole which is traversed by flaming gusts of hydrogen and other gases the nature of which is unknown. Jets of fire which proceed from the very bosom of the sun, traverse with lightning speed the chromosphere and become diffused in the ether of the airs, as motley-shaped clouds, or as bouquets of purple and silver light.

The spectroscope having proved the sun to be a globe of vapours and burning gases, it was

impossible to regard the solar spots as parts of the obscure body of that luminary. M. Faye, the French astronomer, has argued that they are really gaps in the photosphere, produced by the immense currents which traverse it in all directions, and which give rise to whirlwinds and storms of which those that take place on the earth give but a faint idea. According to this theory, the solar whirlwinds and cyclones descend with fury towards the centre of that planet, carrying with them the hydrogen of the photosphere and producing all along their route darkness and a diminution of the temperature. The solar hurricane as it descends, is then supposed to contract in the shape of a funnel, as is the case with terrestrial whirlwinds, and it is the bottom of this projecting funnel that looks like a black spot amid the dazzling brightness of the photosphere.

Thus the new theory, like that of Herschel, would make the spots to be the indications of vast storms, whirlwinds and cyclones in the economy of the sun.

Father Secchi, the great Italian astronomer, and M. Trouvelot, who has devoted much attention to the study of the sun, ascribe the origin of the spots to the violent eruption of flaming substances, which are projected from the central regions of the sun into the photosphere, where

they form enormous dark spots. This theory, which is based upon a number of very interesting observations, has been adopted by M. Janssen of the Meudon Observatory, who, after having observed the passage of Venus over the sun's disc in the Caroline Islands, stopped on his way home in the island of Hawaii, where he passed a night in the crater of Kilauea, at the bottom of which boils a sea of liquid rock. Upon the brink of this sea of fire, he was struck by the curious analogies between this grand volcanic phenomenon and those seen upon the agitated surface of the sun.

Other *savants*, including Professor Young of New Jersey, think that the solar spots are produced by clusters of small stars which, after having eddied round the sun like moths round a candle, fall into its burning envelope, where they appear to us as so many small spots, until they are entirely dissolved in the central furnace. According to this theory, they fall upon the surface of the sun like big drops of rain upon the ground, and this rain is more or less heavy, more or less stormy, according to the size and number of the stars which in clusters, and at regular periods, come to die upon the burning bosom of the sun.

It will be seen that many and interesting as have been the investigations made, we do not yet

know positively what are the origin and nature of the sun spots. One fact appears, however, to be very clear, viz., that they are produced by violent perturbations upon the sun's surface. This violent agitation, these perpetual movements in the midst of the immense atmosphere of fire, must produce torrents of electricity sufficient to act upon the whole of the solar system. And as a matter of fact, to the prodigious storms in the sun, may be said to correspond the electric currents, and the subtle effluvia upon our planet which derange the electric needle, and produce the magnetic storms with their splendid accompaniment of northern lights. It is when the spots are large and numerous, that is to say when the storms in the sun are frequent and furious, that the magnetic storms occur upon the earth. It is then that the magnetic needle oscillates and trembles; that an electric wave produces in the telegraph wires an ebb and flow like that of the ocean, and that floods of electricity, circulating impetuously over the globe, flood the sky, which lights into sudden fire. The whole vault of the sky is flooded with a great light; light clouds, luminous and rosy, fleet in space like so many strange shaped birds, and streaks of fire dart in all directions and speed from the horizon to the zenith, where they meet in a confused and

quivering mass, and form a diaphanous aurora; a glittering and superb corona.

While the magnetic storm is in progress, it often happens that there is a volcanic eruption, that subterranean noises are heard, and that the ground trembles violently over a large tract of country. The subterranean and magnetic storms in that case follow each other so rapidly, the connection between them is so close, that it is impossible to say which is cause, and which effect. Thus it has become the fashion to regard them both as the effects of one and the same cause, and as being produced by the terrible cyclones and eruptions of the sun, and as being the distant echoes and expiring reflections of the latter.

Many astronomers in Europe and the United States have been at the pains to prove the connection there is between these terrestrial phenomena, and those of the sun. Father Secchi at Rome, and M. Wolf of the Paris Observatory, have dwelt more especially upon the connection between the solar spots and the magnetic storms, while Boué, in a remarkable contribution to the Academy of Sciences at Vienna, has pointed out the many earthquakes which have occurred while the sun was being disturbed by hurricanes or eruptions. More recently, M. Naumann, who has devoted much attention to the volcanic phe-

phenomena of Japan, has shown in a very striking way that in that country the greatest eruptions, and most violent earthquakes, have always occurred during the period of disturbances in the sun.

But it is not the sun alone which, by its whirlwinds of fire, or its vast eruptions, provokes the earthquake shocks ; very recent researches tending to prove that at certain epochs the moon, the planets, the asteroids, and even comets stimulate the activity of subterranean forces.

The theory is as follows :--- These countless heavenly bodies form a *cortège* to the sun, which attracts, maintains, lights and warms them, and which carries them in its train. These heavenly bodies, as they gravitate round the sun in turn, approach and move away from it in measured periods, some gravitating alone and others in harmonious groups, some passing rapidly like lightning and in clusters, some slackening their speed when they move away from the sun as if loth to leave it, some speeding towards it at a headstrong and ever quickening pace. And all these stars, which form around the sun, their common lord, such an animated, harmonious and life-like chain, exercise a marked influence upon one another. Infinite in its variety, this reciprocal action depends upon the magnitude of the stars, upon their distance and upon their

position in space. The nearer a planet like the earth is to another star in the solar system, the more it is attracted by it, and if this star is powerful, if its action is at any moment combined with that of a neighbouring star to influence the earth, the latter may be affected to an extraordinary degree. Investigations have been made in view of this, to discover whether at the principal epochs of sidereal influences there have been many severe earthquakes.

As far back as the last century, an astronomer who was attached to the University of Lima published a very curious work which may be called an astronomical time-table of earthquakes, as the years and even the hours when danger is most to be apprehended are noted with precision. Five years later, in 1734, the same author published another book in which he made a fresh set of predictions, observing in his preface that his previous table had been confirmed by 200 earthquakes which occurred at the time indicated by him.

More recent and more methodical investigations have tended to confirm rather than confute his views, for all the years of severe earthquakes seem to correspond with certain astronomical periods, and it has been remarked they recur more especially at the expiration of the cycle of Saros, a period of 18 years and 11 days, after

which the sun and the moon are once more in nearly the same positions. It is the period which the Chaldeans employed to predict the eclipse of the moon and which is still employed to calculate roughly the epochs of eclipses. Now in the table of the Peruvian astronomer, the years indicated as most dangerous form a cycle which corresponds pretty closely with that of Saros.

Nor is this all, for according to the investigations of Herr Falbe, in Germany, and of M. Delauney, in France, each time that the earth, in its revolution round the sun, is brought within the action of a large planet like Jupiter, or a group of numerous asteroids, there are more or less severe earthquakes.

Thus, M. Delauney, after having determined for a certain number of years the epochs at which the earth would once more be subject to marked sidereal influences, went on to venture predictions as to the coming earthquakes. In March, 1877, he announced that severe earthquakes might be looked for in the course of that same year, and several occurred in the month of May upon the western coasts of South America, accompanied by immense waves the reflux of which was felt as far as the shores of the extreme East.

M. Delauney also announced great earthquake shocks for the year 1883, and predicted the time

at which the catastrophe of the Strait of Sumatra, which in a few moments made about 50,000 victims, would occur. This terrible earthquake extended as far as Ceylon and Australia, that is to say over a radius of two thousand miles, forming a circle which represents a fifteenth of the whole area of the globe.

This terrible subterranean shock, from the extent of its sphere of action, was a phenomenon vast enough to be taken as proving the existence of some universal cause such as sidereal attraction. But, severe as this shock was, M. Delauney predicted that 1886 would witness earthquakes still more formidable, and his predictions have caused great alarm in countries subject to these calamities.

Although the French Académie des Sciences has not so far given a very favourable reception to his views, the theory which he has adopted does not seem to me one to be put contemptuously aside. All earthquakes have not a common cause, but among them a powerful sidereal influence might in certain circumstances well be admitted. Inasmuch as the stars, the moon and the sun more especially produce tides in the ocean, it seems natural that they should have a like action upon the sea of fire which, as is believed, exists in the interior of the earth.

Professor Mérian, of Zurich, Alexis Perrey, of

the Faculty of Sciences at Dijon, and many other observers of equal insight have endeavoured to solve the problem. M. Perrey has directed his investigations to 5,388 earthquake shocks of which he was able to obtain the precise date, and the outcome of them is that most of these shocks have occurred at the time of the new or full moon, and especially during the perigee, that is, when the sun and moon are nearest to the earth. These researches have also led to the curious conclusion that earthquakes have been most violent when the moon was at the meridian of the places where they occurred: just as in our ports the ocean tides are strongest and stormiest when the moon is nearest to the earth and passes to the meridian of these ports.

It is quite possible, therefore, that there is a subterranean tide, with its ebb and flow, and that it is subject to the same sidereal influences as the tides of the ocean. Just in the same way, too, when under the influence of the stars which gravitate in the sky, the great wave of fire undulated to and fro in the depths of the earth, then the volcanoes would be more active, the soil would tremble more violently, and man would feel that some unknown danger threatened his existence.

THE EARTHQUAKE IN THE STRAIT OF SUNDA.

The Islands of the Indian Ocean.—The Strait of Sunda.—Java and Sumatra.—Frequency of earthquakes in the Strait of Sunda. Catastrophe of 1883. Eruption of the volcano of Krakatoa.—Shocks at Sumatra and Java.—Destruction of towns and villages. Mainland and islands disappear in the waters.—New isles are upheaved. Eruption of the volcanoes of Java and Sumatra. Enormous waves swallow up the towns of Anjer and Telok Betong. Destruction of the finest Buddhist temples. The number of the killed. Marine undulation. An atmospheric wave oscillates around the earth.—The underground noises are heard at enormous distances.—Aspect of the sun during the earthquake.—Crepuscular lights.

THERE is no region more frequently visited by earthquakes than the beautiful lands in the Indian ocean, which spreading in the shape of a bow from New Guinea to the Bay of Bengal form an immense cluster of islands, carpeted with flowers and bristling with burning volcanoes. Situated in the centre of this cluster of ever trembling islands, the archipelago of the Sunda is notable among all the rest for the violence of its volcanoes and of its earthquakes.

The Strait of Sunda is the passage which separates the islands of Java and Sumatra, and communicates with the Indian Ocean at about the

sixth degree of south latitude. It is one of the most crowded marine highways in the east, sailing vessels always taking this route to go from the Indian Ocean into the sea of China, while it is also the route taken by vessels coming from



Tumultuous Movement of the Floods in the Strait of Sunda

South America, and of those which go round the Cape on their way to and from the far east.

Steamers coming from Europe pass, as a rule, through the straits of Malacca, between Sumatra and the Indo-Chinese peninsula ; but during the south-west monsoon many of them regain the Indian Ocean by the Strait of Sunda, so as to take advantage of the favourable winds which bring them to the entrance of the Red Sea. By the direct route they would encounter very strong

head-winds and a rough sea, while this route, though longer in point of distance, is shorter in point of time.

Issuing from the Strait of Sunda, on the way to the Philippine Islands, China, or Japan, there are three passages to choose from, the Strait of Banca, on the coast of Sumatra, the Strait of Gaspar, between the Island of Banca and Billiton Island, and the Strait of Kamarita, on the coast of Borneo. All these passages are perfectly well known, and they are properly lighted and buoyed by the Government of the Dutch Indies.

In former ages Java and Sumatra formed one single island, but in the year 1115 after a terrific earthquake the isthmus which connected them disappeared in the waves, with all its forests and fertile fields, and so the two were separated (see Raffles' *History of Japan*). Java and Sumatra are the most beautiful and, next to Borneo, the largest islands in the archipelago. Their soil is of matchless fertility, and the animal and vegetable products of their vast forests have no parallel. There blooms the *Rafflesia Arnoldi*, the largest of all flowers, while the most beautiful of birds, the most monstrous of serpents, and wild beasts of every variety are also to be found in them. Above all this wonderful vegetation tower lofty mountain chains, whose volcanic crests rise

to an altitude of 10,000 feet above the wealthy seaports of the two islands.

There are more than a hundred volcanoes in the two islands, half of which have never been explored, but it is known that whenever there has been an eruption of any one of them, one or other of the two islands has been visited by an earthquake.

Moreover, earthquakes are so frequent in the whole archipelago that the principal ones serve as dates to mark time or to refer to, just as in Europe is the case with great wars or any other historic events. A month rarely passes without the soil being shaken, and some village or other human agglomeration situated near a volcano disappearing.

In 1822 the earthquake which accompanied the eruption of the Javanese volcano of Yalung-Yung utterly destroyed 144 towns and villages. In 1772, when the Papandyang was in a state of furious eruption, the island of Japan was violently agitated, and a tract of nearly 25 square leagues, which but yesterday was covered with flourishing villages and farms, was reduced to a heap of ruins. In 1815 an earthquake, accompanied by an eruption of the volcano of Timboro, in the island of Sumatra, destroyed more than 20,000 lives.

In addition to their immediately disastrous

consequences these catastrophes often exercise for, a long series of years a most deleterious influence upon the countries where they have occurred.

Thus in 1869, immediately after a violent earthquake, the great Javanese volcano of Yunong-Salak ejected such a quantity of cinders and lava that all the adjacent water-courses, already disturbed by the earthquake, were completely obstructed. The region became so unhealthy that in twenty-two years epidemics carried off in Batavia alone nearly a million inhabitants, that is to say, 45,000 persons per year, or a fifth of the total population.

It is rare, however, even in this archipelago that there occurs a cataclysm so terrible as that of 1883, caused by the eruption of Krakatoa and other volcanoes.

Krakatoa, where the first eruption occurred, which was, as it were, the signal to the other volcanoes of Java and Sumatra, is, or rather was, an island situated in the middle of the Strait of Sunda, that is to say, in the centre of the most fiery underground furnace that is known to us.

The perturbations in the island of Krakatoa began on Saturday, the 25th of August, with subterranean mutterings, which were distinctly heard as far as Suraperta and Batavia.

At first little heed was paid to them, but at the

•end of a few hours an avalanche of stones began to fall, and during the whole night there was a constant shower of cinders and burning stones.

In the morning, all communication with Anjer, upon the Strait of Sunda, were cut off, the bridges had been destroyed, and the roads had become impassable.

Perturbations occurred beneath the waters of the strait, which roared and hissed violently, while enormous waves broke against the shores of Java. The temperature of the sea had risen by nearly 60 degrees, while at Madura, which is more than 500 miles from Krakatoa, the waves beat against the shore mountains high.

Gradually the underground noises became more distinct, and by mid-day, Maha-Meru, the greatest if not the most active of the Javanese volcanoes, was belching forth flames almost continuously.

The eruption soon extended to the Gunung-Guntur and other volcanoes, until a third of the forty-five craters in Java were either in full blast, or beginning to show signs of eruption.

Shortly before nightfall an immense luminous cloud gathered above Gunung-Guntur, and the crater of this volcano began to emit enormous streams of lava and sulphureous mud; after which formidable explosions were heard, and torrents of

cinders were hurled into the air, together with enormous fragments of rock, which flew in all directions, and did terrible execution as they fell.

While these eruptions were going on, the sea was in a state of tremendous agitation. The clouds floating above the water were charged with electricity, and at one moment there were no fewer than fifteen large water-spouts to be seen at the same time.

Men, women and children fled in terror from their crumbling habitations, and filled the air with their cries of distress. Hundreds of them who had not time to escape were buried beneath the ruins.

On Sunday evening the violence of the shocks and of the volcanic eruptions increased, and the island of Java seemed likely to be entirely submerged. Enormous waves dashed against the shore, and in some cases forced their way inland, while enormous crevices opened in the ground, threatening to engulf at one fell swoop all the inhabitants and their houses.

Towards midnight there was a scene of horror passing the powers of imagination. A luminous cloud, like that which had appeared above Gunung-Guntur, but still more colossal, gathered above the chain of the Kandangs, which run along the south-eastern coast of Java. This cloud

increased in size each minute, until at last it came to form a sort of dome of a gray and blood-red colour, which hung over the earth for a considerable distance.

In proportion as this cloud grew, the eruptions gained fresh force, and the floods of lava poured down the mountain sides without ceasing, and spread into the valleys, where they swept all before them. On Monday morning, about two o'clock, the heavy cloud suddenly broke up, and finally disappeared, but when the sun rose it was found that a tract of country extending from Point Capucine to the south as far as Negery Passorang, to the north and west, and covering an area of about fifty square miles, had entirely disappeared.

There stood the previous day the villages of Negery, and Negery Babawang. Not one of the inhabitants had escaped. They and their villages had been swallowed up by the sea. The population was not so dense in this part of the island as in others, but for all this the total number of victims fell little short of 15,000.

The chain of the Kandangs, which runs along the coast of Java in the form of a semi-circle for a distance of 65 miles, had also disappeared.

The waters of Welcome Bay, in the Strait of Sunda, those of Pepper Bay to the east, and those

of the Indian Ocean to the south, had burst in upon the country, where they formed a raging torrent.

In the night of Monday the Javanese volcano of Papandyang was the scene of several violent eruptions, followed by detonations which are said to have been heard at a distance of fifty miles.

At Sumatra three columns of fire shot up in separate lines, from a mountain the flanks of which were at once covered with torrents of lava. Stones fell at the same time several miles away, and the air was filled with black dust which produced absolute darkness. The phenomenon was accompanied by a whirlwind, which lifted into the air roofs, trees, horses and men. The quantity of ashes which fell was so great that they covered the soil and the roofs of the houses in Denamo to the depth of several inches.

Suddenly the scene changed in the island of Java. The volcano of Papandyang (the "forge") split into seven parts without any noise, and at the spot where a moment before the mountain stood there was nothing to be seen but seven peaks, within whose yawning abysses boiled a mass of liquid matter, from which issued volumes of vapour, and torrents of lava. The lava, descending the slopes of the mountain, formed at the bottoms deposits which extended for several miles. One of the most singular accidents which occurred

during the catastrophe was as follows. Almost at the very spot where the island of Merak had been swallowed up by the sea the previous day fourteen new volcanic mountains, forming a complete chain in a straight line between St. Nicholas Point, on the coast of Java, and Point Hoga, on the coast of Sumatra, suddenly rose into view.

Of the 3,500 Europeans and Americans who were at Batavia, and in the port of Anjer, 800 perished. The quarter of the town of Anjer which they inhabited was first overwhelmed with *débris* of rock, mud, and lava, and then came the waters, which swept away the ruins without so much as leaving a trace of them, and which caused the death of more than 2,000 inhabitants, and of a great number of fugitives belonging to other localities. Bantam was entirely covered with water, and it is believed that twelve or fifteen hundred persons perished there. The island of Serang was completely inundated, and not a single inhabitant survived. At Cheribon the inundations were not so great, but the fall of rocks and the torrents of lava also made many victims there. Buitenzorg, a wealthy pleasure-resort, suffered very much, as also did Samarang, Suraperta, and Surabaya. The "thousand temples" of Brambaham were much injured, some of them completely destroyed.

The great central dome of the celebrated temple of Boro-Buddor disappeared, carried away by the falling rocks. The small town of Tamarang was swept off by the lava, more than half the population, or about 1,800 persons, perishing at Speeswyk. The rocks were like red-hot iron when they fell, and actually set fire to the houses in the most populous part of the town.

The river Jacatana, upon the banks of which Batavia stood, was so filled with lava and *débris* that its waters changed their course, and, making a new channel for themselves through one of the streets of the town, flowed into the Emerades, the level of which they raised very considerably (see *Daily News*, September, 1883). Figelenking was almost entirely destroyed, and a great number of the inhabitants lost their lives.

The island of Onius, which is situated five miles from the mouth of the Targerang and twenty miles to the east of Batavia, after having been violently shaken, was completely submerged, and the island of Midah, ten miles from the coast of Java, was nearly all swallowed up. The towns of Anjer, Tjeringen, and Telok-Betong were destroyed, and all the lighthouses along the Strait of Sunda had disappeared. At Waronge about 900 persons had perished, and at Talatoa, upon the coast, 300 corpses were extricated from the ruins.

All these towns had been destroyed by the combined effects of the volcanic fires, the earthquakes, and the seaquakes.

The ancient temples of Buddha in Java, some of which are the most magnificent monuments in existence, and which in grandeur of aspect are far superior to the pyramids of Egypt, were in part destroyed, the partial destruction of the great temple of Boro-Buddor being especially deplorable. This building, which the natives of Java also call Boer-Buddha and Boro-Bodo, is situated about thirty-six miles from Djockjakarta, upon the shores of the Indian Ocean, at the opposite end of the island to Samarang. Boro Bodo was the largest Buddhist temple in the East, and, with the exception of that of Naku Wat in Cambodia, it had not its equal in the world. This marvellous building, which dates from the eighth century, stood upon an eminence in the midst of a great circular valley, over and around which several volcanoes reared their lofty heads. It was 145 feet high, and was surmounted by a central dome of very fine proportions, and by seventy smaller domes of equal beauty. Beneath these domes were a number of platforms built one above the other, upon which stood 450 chapels, cut in open-work out of the granite, and each having a statue of Buddha in the customary cross-legged attitude.

The wings of the temple were covered with bas-reliefs re-tracing the history of Buddha and of his religion in the most complete fashion, not a single stone being uncarved, and there are, in all, 4,000 separate bas-reliefs, which, though grotesque to Western eyes, are clearly and delicately chased, and are rich in details and general outline. Four grand staircases, of 500 feet each, led to the chapel upon the summit, an elegant sanctuary, of which the dome was a marvel of beauty.

The "Thousand Temples," or *Chandi-Siva*, situated at Brambaham, upon the site of the ancient capital of Java, about twenty miles from Boro-Bodo to the south-east, were, as already mentioned, much injured by the tidal wave, the earthquake and the volcanic eruption. The "Thousand Temples" form a group of very striking churches, but they are in a very exposed situation, being close to the volcanic mountain of Merapia, which contributed so much to the magnitude of the disaster.

The island of Merak, which was destroyed by the trepidations of the land and sea, was a fortified place, situated three miles from the volcano of Krakatoa, in a region very rich in quarry stone. These quarries were opened up about six or seven years ago, the Government requiring a large quantity of stone for building new quays and docks

at Batavia, and they yielded from that time 1,500,000 tons of stone. Thousands of workmen, most of them natives, were at work there, and, together with the engineers and overseers, lived upon the hills about 150 feet above the level of the sea. All of them perished except two natives and a European bookkeeper, and the material damages amounted to 120,000/. The disaster was all the more sad because work in the quarries was to have been suspended on the 1st of September, so that if it had occurred four or five days later, very few lives would have been lost, as most of the workmen would have returned to Batavia.

The news of the destruction of the town of Telok-Betong, upon the coast of Sumatra, reached Batavia, by a steamer from that port which was at sea at the time of the eruption. This steamer made for Anjer in order to warn the inhabitants, but it found that town already destroyed.

The deck of the steamer was covered with a layer of volcanic ashes two inches deep, and the captain of the vessel states that for some time he had to pick his way amidst a mass of pumice stone eight or ten feet deep which was floating upon the surface of the sea.

From the deck of this vessel was seen the terrible catastrophe of Telok-Betong, which an eyewitness describes as follows :--“ We saw a

gigantic wave of prodigious height suddenly advancing upon us at great speed from the direction of the open sea. Immediately, the captain brought his vessel round so as to meet the wave stem foremost. After a moment of poignant anxiety, we found ourselves lifted up with terrific speed ; our vessel bounded upward, and then we felt ourselves again plunged into the abyss. But the wave had passed us, and we were out of all danger. Like a high mountain, the gigantic wave sped furiously towards the shore while, immediately after, three other great waves followed it. Thus we had before our eyes the terrible spectacle of the waters rushing in and destroying the town, sweeping away first the lighthouse, which fell in like a pack of cards, then all the buildings beyond. In a few moments all was over, and where once Telok-Betong stood there was soon nothing but water. Words are vain to describe the impression which this cataclysm made upon us. The instantaneousness of the change, the gigantic proportions of the tragedy, and the sudden devastation which it produced combined to stupefy our senses and to make us think that we were the victims of an evil dream instead of the witnesses of a dread reality. We ourselves, who had been spectators of the tragedy, were threatened with imminent danger, and had a narrow escape of a terrible death."

Anjer, which on the day following the catastrophe was a mere heap of ruins, had but a few hours before been a charming little port, surrounded by a belt of verdure, out of which rose one of the finest trees in the archipelago, a banana which could be seen from a considerable distance out at sea, and whose branches formed a dome 490 feet in circumference.

Upon the 27th, at 6. A.M., while the inhabitants were still in bed, a vast wave dashed with violence upon the shore, its waters forcing their way into the town, and as they receded, carrying with them men, women and children. The fort of Anjer, with its large Dutch garrison, had disappeared in the waters. But this was only the beginning; a thick shower of ashes filled the air, and a second wave, more than a hundred feet high, burst upon the town and carried back with it what little the first wave had left. As a sailor, contemplating the site from the deck of his ship the following day, exclaimed: "There is no longer a town of Anjer left."

Another sailor, a pilot, who was on the sea-shore when the enormous mass of dark water came rushing on with the noise of thunder, and who was the sole survivor of the catastrophe, described what occurred to him as follows:—
"Feeling that my end had come, I commended

my soul to God. By a supreme effort, I had kept myself upon the surface, and in whatever direction I looked, I could see nothing but the waters of the sea. At last, I drifted on to a tree. Where before stood the town of Anjer, I could see nothing but a stormy sea from which emerged the tops of the trees and a few turtles. Suddenly the waters abated and flowed back to the sea. They soon had receded altogether, and I was able to come down from the tree without any danger. I went in terror through the streets of Anjers, but upon all sides I saw nothing but death and destruction. The town was one heap of ruins, and corpses lay about in all directions. I was so horrified that I made off in the direction of Serang."

It was feared that the earthquake would have blocked the Strait of Sunda, and when one remembers that the waves raised up by the oscillations of the bed of the sea were at least 130 feet high, it is easy to understand the destruction it must have wrought in this strait, and it swept everything upon its path, upon the coast of Sumatra as well as upon that of Java.

The island of Krakatoa, which was 25 miles long and 17 broad, sunk nearly entirely into the sea, while its volcano was belching forth torrents of fire, while its soil was trembling and while gigantic waves were breaking upon the shore.

• Other islets sprang up in the place of those destroyed, completely changing the shape of the strait and so disturbing the geographical condition of the coast that after the catastrophe the marine charts were of no use, the European Governments being obliged to telegraph to all vessels on their way through the Strait of Sunda to put them upon their guard. Fresh charts had to be made, and nearly all the powers which have hydrographical missions in the East lent their assistance to the Dutch officials in preparing them.

Although the precise number of victims is not known, it cannot have been less than 50,000, and probably was as many as 60,000. In the island of Java alone, more than 15,000 persons perished, and 10,000 at Tjeringen. Although the population of the north of Bantam, which suffered so severely, had decreased in the previous years, it still amounted to half a million at the time of the 1883 earthquake, so that it is not astonishing that at first the total number of victims should have been estimated at 80,000 and even more.

The earthquake lasted three days and three nights, and its effects were felt over an immense surface of the globe, thousands of miles from the scene of the disaster. The enormous wave which in the morning of the 27th had ravaged the Javanese coast and swallowed up the town of Anjer,

rolled back through the Indian Ocean and reached, at about two the same afternoon, the Mauritius and the island of Bourbon, having covered a distance of 1,300 leagues in eight hours, and thence crossing the Atlantic it reached the shores of France and America, where sudden high tides were observed.

While the marine undulation which commenced in the Strait of Sunda created such great disturbance in distant seas, an atmospheric wave, which had its origin in the same region, spread in all directions, and in a very few hours made thrice the circuit of the globe. The subterranean detonations were heard as far as Ceylon and even Australia, more than 2,000 miles away, and it is even said that they extended to the other extremity of the globe and were audible in the Caymans, a group of three small islands in the Caribbean Sea, which are the antipodes of the island of Java.

The sun presented a very singular appearance in Ceylon during the earthquake, disappearing altogether for a time and then being covered with dark spots visible to the naked eye. At Paramaribo, in South America, the sun, though very limpid, was of a light blue indigo tint from morning till night, and the natives regarded this as a forecast of evil. In Europe, the sunsets were singularly beautiful, their iridescent and opaline tints resembling the fires of the aurora borealis.

EARTHQUAKE IN NEW ZEALAND.

“THE EIGHTH WONDER OF THE WORLD!”

THE recent eruption of Mount Tarawara in New Zealand destroyed the famous White and Pink Terraces, the most marvellous sights in the wonderful Hot Lake district of the southern hemisphere. Their disappearance lends additional interest to the chapter devoted to them in his “Oceana” by Mr. Froude, who was the last English traveller to describe them, having visited them during his Australasian tour. The road to Wairoa, by which the famous terraces which Mr. Froude calls “the eighth wonder of the world” were reached, crossed a wide plain, from which could be discerned the smoke of distant geysers. On emerging from beneath the trees of a forest through which the party passed—

We found ourselves on the edge of a circular lake or basin of beautifully transparent sapphire-coloured water, a mile in diameter, with no stream running into it or out of it, and closed completely round with woods, cliffs, and rocky slopes. No boat or canoe floats upon its myste-

rious surface. It is said to contain no living thing save a dragon, who has been seen on sunny days to crawl upon a bank to warm himself. I was reminded instantly of the mountain lake in the "Arabian Nights" where the fisherman drew his net at the bidding of the genius. Here, if anywhere in the world, was the identical spot where the five fish were taken out—red, blue, yellow, purple, and green—who terrified the king's cook by talking in the frying-pan. The dragon might really be there for anything that I could tell: anything might be there, so weird, so enchanted, was the whole scene. Following the beach for a quarter of a mile, and listening to the voices of the waves which rippled on the shingle, we turned round a shoulder of rock, and saw, a hundred feet below us, and divided from the blue lake only by a ridge over which a strong hand might throw a stone, a second lake of a dingy green colour—not enchanted this one, but merely uncanny-looking. I suppose below both there are mineral springs which account for the tint. Out of the green lake a river did run—a strong rapid stream, falling in cataracts down a broken ravine, and overhung by dense clumps of trees with large glossy leaves. The road followed the water into a valley, which opened out at the lower end. There stood Wairoa with its inhabitants.

- The White Terrace was approached from Wairoa by the Tarawara Lake, the head of which was overhung with precipitous cliffs, a hot spring bubbling violently through a hole in the rock.

Stretched before us we saw the White Terrace in all its strangeness : a crystal staircase glittering and stainless as if it were ice, spreading out like an open fan from a point above us on the hillside, and projecting at the bottom into a lake, where it was perhaps two hundred yards wide. The summit was concealed behind the volumes of steam rising out of the boiling fountain, from which the silicious stream proceeded. The stairs were about twenty in number, the height of each being six or seven feet. The floors dividing them were horizontal, as if laid out with a spirit-level. They were of uneven breadth ; twenty, thirty, fifty feet, or even more ; each step down being always perpendicular, and all forming arcs of a circle of which the crater was the centre. On reaching the lake the silica flowed away into the water, where it lay in a sheet half submerged like ice at the beginning of a thaw. There was nothing in the fall of the ground to account for the regularity of shape. A crater has been opened through the rock a hundred and twenty feet above the lake. The water, which comes up boiling from below, is charged as heavily as it

will bear with silicic acid. The silica crystallizes as it is exposed to the air. The water continues to flow over the hardened surface, continually adding a fresh coating to the deposits already laid down ; and, for reasons which men of science can no doubt supply, the crystals take the form which I have described. The process is a rapid one : a piece of newspaper left behind by a recent visitor was already stiff as the starched collar of a shirt. Tourists ambitious of immortality had pencilled their names and the date of their visit on the white surface over which the stream was running. Some of these inscriptions were six and seven years old, yet the strokes were as fresh as on the day they were made, being protected by the film of glass which was instantly thrown over them. The thickness of the crust is, I believe, unascertained, the Maories objecting to scientific examination of their treasure. We walked, or rather waded upwards to the boiling pool ; it was not in this that we were to be bathed. It was about 60 feet across, and was of unknown depth. The heat was too intense to allow us to approach the edge, and we could see little from the dense clouds of steam which lay upon it. We were more fortunate afterwards at the crater of the second terrace. The crystallization is icelike, and the phenomenon, except

for the alternate horizontal and vertical arrangement of the deposited silica, is like what would be seen in any northern region when a severe frost suddenly seizes hold of a waterfall before snow has fallen and buried it.

Leaving the White Terrace, the travellers were introduced to another of the various wonders awaiting them.

“Columns of steam were rising all round us. We had already heard, near at hand, a noise like the blast-pipe of some enormous steam-engine. Climbing up a rocky path through the bush, we came on a black gaping chasm, the craggy sides of which we could just distinguish through the vapour. Water was boiling furiously at the bottom, and it was as if a legion of imprisoned devils were roaring to be let out. ‘Devils’ Hole’ they called the place, and the name suited well with it. Behind a rock a few yards distant we found a large open pool, boiling also so violently that great volumes of water heaved and rolled and spouted, as if in a gigantic saucepan standing over a furnace. It was full of sulphur. Heat, noise, and smell were alike intolerable. To look at the thing, and then escape from it, was all that we could do, and we were glad to be led away out of sight and hearing. Again a climb, and we were on an open level plateau, two

acres or so in extent, smoking rocks all round it, and, scattered over its surface, a number of pale brown mud-heaps, exactly like African ant-hills. Each of these was the cone of some sulphurous geyser. Some were quiet, some were active. Suspicious bubbles of steam spurted out under our feet as we trod, and we were warned to be careful where we went. Here we found a photographer, who had bought permission from the Maori, at work with his instruments, and Marileha was made to stand for her likeness on the top of one of the mud-piles. We did not envy him his occupation, for the whole place smelt of brimstone and of the near neighbourhood of the Nether Pit. Our own attention was directed specially to a hole filled with mud of a peculiar kind, much relished by the natives, and eaten by them as porridge. To us, who had been curious about their food, this dirty mess was interesting. It did not, however, solve the problem. Mud could hardly be as nutritious as they professed to find it, though it may have had medicinal virtues to assist the digestion of cray-fish."

The travellers were next ferried in a canoe across the hot lake to visit the Pink Terraces on the opposite shore :—

It was formed on the same lines as the other, save that it was narrower, and was flushed with

pale-rose colour. Oxide of iron is said to be the cause, but there is probably something besides. The water has not, I believe, been completely analysed . . . The crater at the White Terrace had been boiling; the steam rushing out from it had filled the air with cloud, and the scorching heat had kept us at a distance. Here the temperature was twenty degrees lower; there was still vapour hovering over the surface, but it was lighter and more transparent, and a soft breeze now and then blew it completely aside. We could stand on the brim and gaze as through an opening in the earth into an azure infinity beyond. Down and down, and fainter and softer as they receded, the white crystals projected from the rocky walls over the abyss, till they seemed to dissolve not into darkness but into light. The hue of the water was something which I had never seen, and shall never see on this side of eternity. Not the violet, not the harebell, nearest in its tint to heaven of all Nature's flowers; not turquoise, not sapphire, not the unfathomable ether itself could convey to one who had not looked on it a sense of that supernatural loveliness. Comparison could only soil such inimitable purity. The only colour I ever saw in sky or on earth in the least resembling the aspect of this extraordinary pool

was the flame of burning sulphur. Here was a bath, if mortal flesh could have borne to dive into it! Had it been in Norway, we should have seen far down the floating Lorelei, inviting us to plunge and leave life and all belonging to it for such a home and such companionship. It was a bath for the gods and not for man. Artemis and her nymphs should have been swimming there, and we Actæons daring our fate to gaze on them. This was the end of our adventure—a unique experience.

THEORIES AND CONCLUSION.

I.

The central fire.—Theories and hypotheses which it has suggested.
—Why the existence of the central fire is admitted.—What the interior of the earth might be like. A sun concealed in the bowels of the earth.—Gradual contraction of the earth's crust.—Falling in of caverns and settling down of rocks.
Electricity considered to be a cause of earthquakes.—The cycle of the seasons.—The sidereal influences.

MANY efforts have been made to probe the mysterious cause of these great phenomena, and to discover what is the hidden force which agitates so violently the earth (which our inborn instinct leads us to believe motionless), and I will bring my work to a conclusion by setting out the theories to which researches into this matter have given rise. Most of them having been set forth in the preceding pages, I need not do more than summarise them, giving special prominence to some recent investigations.

First let me mention the theory of Humboldt, which is remarkable for its ingenious surmises and its tendency to generalise isolated facts. According to this theory, volcanoes and earthquakes are the effects of the central fire. In

other words, they are the elastic fluids, the gases, and the vapours which, formed by the seething mass and rising suddenly to the strata nearer the surface, produce the shocks which are felt on the earth, before finding their way through fissures and crevices, or through the mouths of volcanoes, into the atmosphere.

Many geologists, among them the brothers Henri and Charles St. Clair-Deville and M. Daubrée, the director of the French School of Mines, while admitting the existence of the central fire, add that, by means of fissures and by a gradual filtration, the rain water as well as that of the ocean penetrates into the warm regions of the earth, where it becomes transformed into vapour. This vapour, circulating in all directions in the depths of the earth, and being in turn condensed and dilated, would produce explosions and agitate the soil ; in other words would be the cause of earthquakes.

An eminent English geologist, Poulett Scrope, who has devoted much attention to volcanic phenomena, holds that the underground rocks now and again increase in temperature by an uprush of heat from the great internal furnace. This sudden change of temperature would produce in the mineral mass dilatations, vibrations and undulations which upon the surface would be felt as earthquake shocks.

Robert Mallet, an English geologist who also has devoted a great deal of attention to earthquakes, regards the submarine volcanic eruptions as the most fertile source of earthquakes. He holds



A Traveller Contemplating the Ruin wrought by an Earthquake.

that the eruption of matter in a state of fusion, taking place under the sea, must open in the rocky bed enormous fissures, through which the water reaches the surface of the burning lava; and that when this contact takes place, an immense quantity of vapour escapes and disappears in the deep cold water of the sea, undergoing condensation in its course. A formidable

shock would thus be imparted to the volcanic focus, and this commotion, spreading in all directions, would produce the shock upon the surface. No doubt exists that an eruption of this kind may be the cause of violent shocks in islands and land close to the sea, but it is hard to believe that the great shocks in the middle of continents, hundreds of miles from the sea, can be due to submarine eruptions.

Rogers, the American geologist, thinks with Humboldt, Arago, Elie de Beaumont, Leopold Buch and many others, that earthquake shocks are produced by the central fire, but he does not agree with them that they are due to the action of the gases heated to the highest point by this internal fire. In his view, these phenomena are excited directly by a pulsation of the inflamed matter—a pulsation which would spread and open out like a vast wave. He believes the interior of the earth to be composed entirely of matter in a state of fusion, and the crust which envelopes this vast fire to be so thin that the undulations of the waves of fire cause it to undulate just as a marine wave lifts a raft or a vessel above it. In other words, the shock upon the surface of the earth would be the echo of a sudden disturbance in the central fire.

This theory is as ingenious as it is simple.

But it does not seem as if an oscillation of this kind would be felt simultaneously in all parts of the terrestrial surface. The reason why the centre of the earth is supposed to be a body of fire, is that our planet is held to have originally formed part of a cosmic mass similar to a flaming gas. According to this hypothesis, put forward by Immanuel Kant, adopted by Herschel and developed with great talent by Laplace, the space now occupied by the sun and the planets was, at the beginning, filled by an immense nebula, from which the sun, and afterwards the earth and the other planets became detached. The earth, at first in a state of fiery gas, gradually cooled down and finally formed the solid crust upon which we live, while the fire is still burning beneath our feet. Compared to the volume of the earth, this crust is but skin deep.

This theory seems all the more tenable because the heat increases the lower one descends into the bowels of the earth. In the regions explored by miners, in the shafts sunk in the flanks of mountains, and in the deeper natural cavities, the heat is always greater than upon the surface. When one goes down in a mine the temperature increases several degrees, varying of course with the nature of the soil, every hundred yards, and it is estimated that at a distance of thirty miles

EARTHQUAKES.

The observations are interesting, but the conclusion drawn from them is open to objection, for the depth of the greatest excavations made—of the artesian wells in Germany and the silver mines in Mexico and Nevada—is about five furlongs, and this is a mere trifle compared to the distance, 3,900 miles, between the surface and the centre of the earth, and it seems hazardous to draw conclusions from what occurs in so small a fraction of the whole.

Many natural philosophers and astronomers in England, France, and elsewhere have expressed doubts as to the igneous fluidity of the central regions of the earth. Emanuel Liais, the vigilant astronomer at Rio Janeiro, set himself to prove, about twenty years ago, that by virtue of astronomical phenomena the nucleus of the earth must be solid. Ampère was inclined to hold the same opinion, and Sir Humphry Davy also thought that the centre of the earth formed a solid and

opaque mass. Having ascertained the singular fact that certain metals which he had discovered, such as potassium and sodium, become inflamed by the mere contact of water and air, he put forth the theory that at some remote period, before the last revolution in the globe, these metals, which were not as yet oxidized and which lay in vast quantities upon the surface already growing cold, took fire spontaneously and communicated the fire to the elements around them, the flint, the lime, the magnesia, and the aluminium, which we now find in abundance, being the oxides of these metals.

In the opinion of Sir Humphry Davy the centre of the earth is a metallic non-oxidized mass. The fluids of the upper strata in penetrating to these depths do not do more than oxidize the surface of this solid kernel ; but this chemical action, this continual oxidizing process, develops an intense heat which, extending towards the exterior of the globe and also towards its interior, keeps up the volcano fires and produces earthquakes. As, starting from the point of contact, the heat provoked by the action of the liquids upon the metallic nucleus decreases towards the terrestrial surface as well as towards the central region, it may be assumed that the temperature at the centre of the earth is very low. Moreover,

according to Sir Humphry Davy's disciples, as the igneous sphere began to cool not at the surface but in the densest of central regions, the nucleus must be solid as well as cold.

In England and the United States many contemporary men of science hold this view, and one of the most distinguished, Sir William Thomson, the electrician, has established (see the *Philosophical Magazine*, the *Density of the Earth*, &c.) that the density of the earth is greater than that of iron. Other geometers have been content to prove that if the terrestrial nucleus is in a state of igneous liquidity the crust which covers it is much thicker than many would have us believe, and Sartorius von Waltershausen, the German geologist, who has examined so many great volcanoes, arrived at the conclusion that the centre of the earth is solid, but that there are numerous lakes or seas of fire scattered about at a depth of sixty miles or so from the surface.

According to this hypothesis, which has many adherents, the heat produced by perpetual chemical actions and reactions, by determining in the depths of the earth the fusion of mineral substances already cooled, would form innumerable reservoirs of burning lava, which would thus become fixed in solid partitions, just as

honey is in the cells of a hive. It would be with these lakes that the chimneys of volcanoes communicate, and it would be their fire that produces most of the terrestrial disturbances.

Several modern geometers, looking at the question from another point of view, admit that the internal temperature of the globe is very high, but they hold that in spite of this heat the pressure to which the central mass is subject must prevent its liquefaction. They add, however, that around the central nucleus there may be, wherever the pressure is less, a shallow sea of liquefied minerals, the movements of which may give rise to volcanic phenomena and to the oscillations of the soil.

The boiling waters of the Iceland geysers and of the National Park in the United States, the floods of fire which issue from the mouths of volcanoes, the flames which dart forth from the soil when it trembles are all so many positive proofs that there is in the depths of the earth a source of heat, of fiery gases and liquefied rocks which from time to time cause the ground to tremble, and which emerge from it in jets of flame and liquid lava. But if the whole of the earth's interior was one vast fire, it seems as if the slightest abnormal agitation of this globe of fire would not merely shake or rend here and

there the terrestrial surface but split it into myriads of small fragments.

It may be that the inferior region of the earth, that situated about 60 miles below the surface, is an immense sea of liquefied rocks, varying in depth and having for its bed the solid nucleus of our planet—a nucleus whose protuberances and asperities emerge from the burning sea like islands or continents, and support the vast upper vault which, exposed to the various influences of the sun and the sky, is inundated with living waters, penetrated with vivifying life, covered with verdure and peopled with human beings.

Man, after all, learned as he may be or may think himself, knows nothing certain of all this, and it may be that the great central fire really does exist in the bosom of the earth. If so, and if the physical laws of the surface reign also in the depths, this great liquid globe, this hidden sun, must have its rotary movement. It must revolve in the same direction as the envelope of solid matter which covers it, though at a different rate of speed, it must turn freely within its crust, from which it is separated by an atmosphere of vapours and gas—an atmosphere ever stormy and agitated and constantly traversed by currents of electricity and magnetism.

The theory of the central fire is a grandiose

conception, which explains a series of important facts and which by its magnitude impresses the mind, while the idea which it gives of planetary life inspires us with a sentiment of admiration mixed with wonder and respect.

Many contemporary geologists believe that earthquakes are due to the gradual contraction of the earth's crust, which continues still to get colder, and also to the gradual cessation of the swaying of this crust. The latter motion, which formerly more pronounced, led to the upheaval of continents and to the formation of mountain chains, still, according to this theory, goes on, but it meets at times with more resistance in the adhesion of rocks, and it is when this resistance suddenly gives way that the shocks and upheavals which constitute earthquakes occur.

Darwin, Boussingault, Virlet, Otto Volger and other *savants* consider the principal cause of earthquakes to be the settling down or breaking up of underground caverns through the pressure of the overlying masses of soil. Boussingault and Darwin, who knew South America so well, having observed that most of the earthquakes in this region of volcanoes occur without any eruption taking place, give it as their opinion that in the interior of the Andes there are deep cavities the walls of which give way beneath the great

pressure put upon them. These subterranean landslips would account for the shocks, which are so frequent in this vast region, and it may further be noticed that the noise which they occasion is so similar to that heard when the gallery of a mine gives way that miners have only one word (*bramidos*) for the two phenomena.

In his work upon Swiss earthquakes (*Erbdeden in der Schweiz*) Otto Volger points out that the shocks produced by the underground rocks when they suddenly give way is very like that produced by the fall of glaciers. He observes that in the latter case the spectacle which we have before our eyes distracts our attention from the shock produced, whereas in the case of rocks giving way beneath the surface of the soil, all our interest is concentrated upon the external effects which they produce, these being the only ones we can see. But the various parts of the solid crust of the globe are furrowed by large crevices into which at certain times masses of rocks tumble, their fall often setting up a motion in the subterranean strata. Volger thinks, and most people will agree with him, that a shock of this kind, no matter at what depth it occurs, must extend to the surface of the soil.

This hypothesis it will be seen, attributes earthquakes to the lack of cohesion in the masses of

rock. The water of the springs, by its eroding action, finally breaks up the friable strata composed of substances easy to dissolve, and forms cavities which may well acquire great dimensions. If a mountain sapped at its base sinks ever so little, it will produce violent shocks upon the surface. Thus when in 1840 a lofty mountain in the Jura district subsided, and caused a violent earthquake, the inhabitants attributed this occurrence to a spring which had disappeared twenty years before, and sapped the base of the mountain.

The shocks and quiverings of the terrestrial surface, have often seemed to *savants* to be not unlike the shocks produced by electricity in organized bodies, the more so as earthquakes are often, if not always accompanied by great electric phenomena. Thus many people have come to regard electricity as the cause of great earthquake shocks ; among others Steffens, who in his *Essais Géologiques*, affirms that hot springs, earthquakes and volcanic eruptions, only occur in places where there are veins of coal because they alone can keep up a strong electric tension in the great electric-motor apparatus of the earth.

Humboldt, in referring to this opinion, points out, however, that the nature and disposition of the strata in the interior of the earth, do not seem

to warrant this hypothesis of a vast electric pile, causing shocks upon the surface of the earth, and imparting by the chemical effect of the electro-motor apparatus, that extraordinary fixity of mixture and gravity, which we know to exist in all thermal waters.

Count Bylandt Palsterscamp, the eminent geologist, believes electricity to be the source of the great subterranean phenomena, and he makes a clear distinction between the fire of subterranean combustion, and the electric fire. The latter is superior to, and the cause of the former; it is a subtle fire which penetrates the earth, and gives rise to the volcanic phenomena, as well as to the disturbances of the soil.

Dr. Hefer, whose varied and ingenious researches, have more than once cleared up many obscure points of science, also sees in electricity the cause of earthquakes. Having, like many others, remarked that they are always accompanied by electric phenomena, he concludes that they are the outcome of storms in the interior of the earth. Starting from this principle, he divides storms into three classes:—the atmospheric storms, the underground storms and the mixed storms, during which latter the underground electricity, discharging itself into the atmosphere, would cause earthquakes in the process.

The apparition of the aurora borealis, and of magnetic phenomena during underground commotions has led many investigators to think that terrestrial magnetism is the motive principle of these phenomena. Ami Boué takes this view in his report to the Vienna Academy of Science, but while admitting that it may be the main cause, he ascribes considerable influence to the sudden dilating of gas, and sharp variations of temperature in the interior of the globe.

André Poey in his contributions to the French Académie des Sciences, thinks that earthquakes are due to the action of atmospheric whirlwinds and cyclones, which sweep over the surface, and he adduces in proof of this theory the shock which occurred in Cuba in 1844 during a storm which did immense damage, especially at Havanna. He might have cited in proof of this argument, many shocks which have occurred in the East and West Indies during a cyclone, and also in Central America; but, though he does not mention these, he is confident that the rotary movement of the column of air extends to beneath the soil; nor is he alone in his opinion.

Other naturalists regard the sudden pressures and depressions in the atmosphere, that is to say the sudden variations of the barometer, as the essential causes of earthquakes. though Emil

Kluge, who has paid as much attention to subterranean phenomena as any *savant* of the present day, while believing this to be the cause of slight shocks, gives his adhesion to the theory of the central fire, as developed by Sir Humphry Davy.

Upon the other hand, M. Francis Laur, a French engineer, has recently sought to prove that the volcanic eruptions, as well as the most severe earthquake shocks, are due to sudden atmospheric pressure ; while other observers, taking a general survey of the facts which indicate a connection between the aerial and the underground world, fix the cause of earthquakes, not in the interior of the earth, but in the climacteric phenomena which are produced by the alternation of the seasons ; in the brusque oscillations of the gravity and the temperature of the air, oscillations which are communicated to the elastic fluids in the depths below ; in the great equinoctial tides which penetrate the subterranean cavities and break them up ; in the rain and melting snow which, filtering slowly through the deep strata of the earth, cause internal landslips, which in turn cause the earthquakes on the surface. Of late years it has been remarked how close is the connection between the subterranean world, and certain great phenomena of the celestial world, notably as regards the concurrence of earthquakes with the appear-

ance of the solar spots. Others, again, have pointed out the influence which planetary attractions exercise upon the subterranean forces, while Alexis Perrey and others, admitting that it is difficult to assign a single cause for earthquakes, have held that the moon, when full, sets up a great agitation in the bosom of the earth, and so causes it to tremble (see Chapter I.).

II.

- Underground heat the main cause of earthquakes.—The underground thunder and the disturbance of the soil. The earth and the heavenly bodies.—Incalculable energy of the forces which the earth nurses within her.

As to which of all these theories is the true one I will not take upon myself to say, but I will add that, in my opinion, earthquakes have not all a common origin, and that the theory which attributes them to multiple causes, commends itself to me the most, while, if asked to define my views more closely, I should reply much as follows :—

Earthquake shocks, the sphere of action of which is limited, are generally due to various causes, chief among which I should place the gradual contraction of the earth's crust, the sub-

sidence of mountains and underground landslips. But I do not hold with Boussingault, Darwin and Volger, that this contraction, or these landslips, on however large a scale, suffice to explain the immense commotions which shake at the same time a great part of the globe. These are produced by a general cause, by the same agent which provokes the eruption of volcanoes ; and this force is heat.

Universal and all-penetrating, dreadful and beneficent, cause of life and death ; heat is perhaps the most active of all the essential principles of nature. This powerful agent has its home in the interior of the earth, as we can test¹ for ourselves, by descending into a mine or looking down a volcano. I do not refer to the central fire, for I do not know whether it exists, and whether the heat is greater at the centre of the globe than in other parts of the interior. What we can affirm with confidence is that effluvia of heat do circulate in the interior of the planet, though we are ignorant as to how they are distributed,

It is certain that these effluvia keep up a vast conflagration in the interior of the globe, for we see flames and torrents of boiling lava pouring forth from these depths, within which the rain and water which filter through them are instan-

taneously converted into vapour. Around the immense furnace, where burns fire everlasting, the vapours and gases are subjected to such a tension and dilatation that they cause the floods of matter in fusion to heave and fall, pressing violently against the superincumbent mass of solid rock. Sometimes this mass of rock, yielding to the pressure, breaks up and opens a passage for the fire and the elastic fluids. When this occurs, we have the volcanic eruptions, but at other times the solid mass of rock, instead of breaking up, resists the pressure from below, though it heaves and vibrates so violently that the earthquake is caused upon the surface of the ground.

If the same law prevails in the depths below as upon the surface, this vast process which is kept up and fed by the innate heat of the earth, must give birth to floods of electricity and magnetism, for here on the surface electric effluvia are produced wherever the heat is very active. Heat, light, magnetism, and electricity are visibly being transformed into and substituted for one another, as if they were condemned to a perpetual metamorphosis.

In the bosom of the earth, the electric fire must shoot through these torrents of elastic fluids and overheated vapours which are ever in a state of

alternate dilatation and condensation. It is probable, therefore, that these storms of thunder and lightning rage in the inferno which is beneath our feet, and I often fancy that the earthquake with its short quick shocks, is but the echo of the electric storm beneath.

But I also believe that the celestial bodies stimulate the subterranean forces, and that the sidereal influences which descend from heaven to earth penetrate into its depths. It would seem as if the moon, especially, owing to her power of attraction, must produce in the midst of the fiery matter of the abyss, an agitation similar to the tide to which she gives birth in the ocean ; and it may be that the great subterranean tide sometimes imparts violent shocks to the surface of the soil.

The terrestrial globe is not all of clay ; it is not condemned to an unchanging rigidity, as it would be if made by human hands. The energies which the earth has in store are boundless, and the source of life which circulates within her is inexhaustible. While she speeds round the sun which carries her along into illimitable space, while she is pursuing her endless journey in the immensity of the firmament, she is ever vibrating, ever sculpturing and adorning her splendid surface, ever beautifying and perfecting herself in

her ever renewing youth. But if she is able to do all this, it is because she is not isolated in her activity, but is engaged in an exchange of forces and influences with the other planets in the solar system.

THE END.

